This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

NYPL RESEARCH LIBRARIES
3 3433 06633336 4

Nulla dies sine Linia.

No. ~~3~~ 18.

BELONGING

TO THE LIBRARY

OF

J. T. CLARKE.

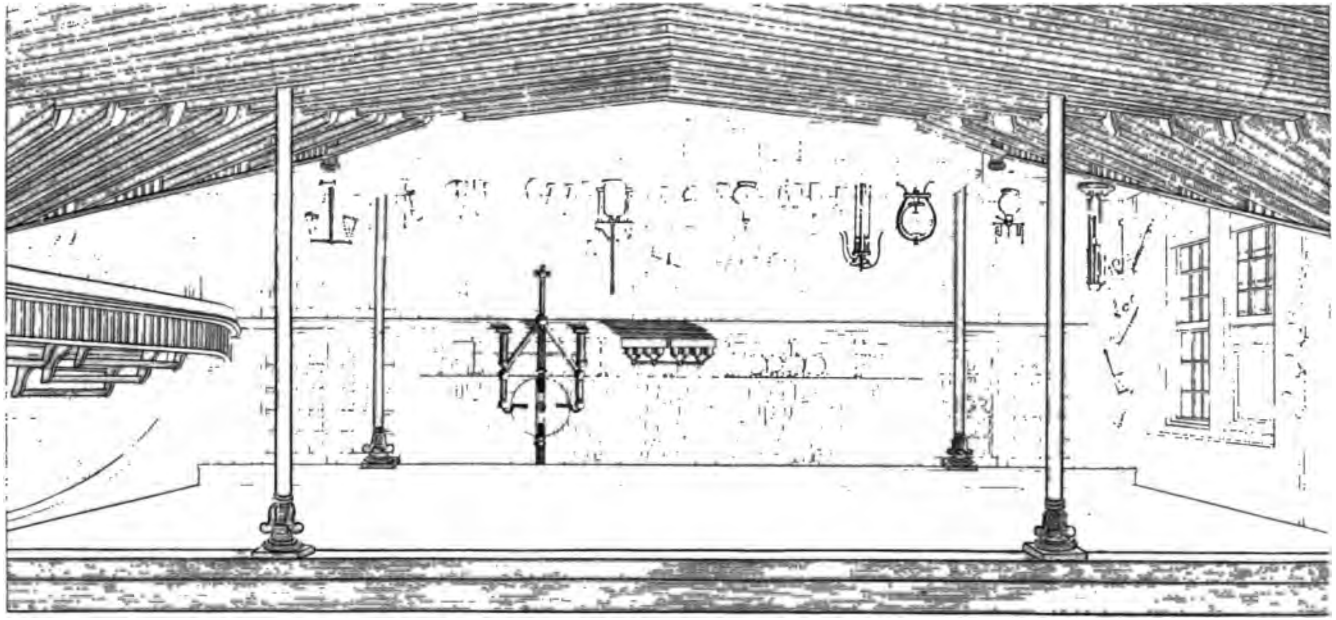
PKO
Hare

Mr. J. E. Clarke
[illegible] Harper
Pa

[illegible]

PUBLIC [illegible]

[illegible]



[illegible]

1842

A

COMPENDIUM

OF

THE COURSE OF CHEMICAL INSTRUCTION

IN THE

MEDICAL DEPARTMENT

OF

The University of Pennsylvania.

BY

ROBERT HARE, M.D.

PROFESSOR OF CHEMISTRY.

PRINTED FOR THE USE OF HIS PUPILS.

THIRD EDITION;

EDITED IN THE ABSENCE OF THE AUTHOR,

BY

FRANKLIN BACHE, M.D.

PHILADELPHIA:
J. G. AUNER, No. 331, MARKET STREET,

John C. Clark, Printer.
1836.

216526B

PREFACE

TO THE FIRST EDITION.

Where a subject cannot be followed by a reader without *study*, it would seem unreasonable to expect that, without some assistance, it should be followed at a lecture.

Under this impression, from the time that I became a lecturer, I applied myself so to improve and multiply the means and methods of experimental illustration, as to render manipulation easier, and the result more interesting and instructive.

But notwithstanding all my efforts, there remained obstacles to be surmounted. However striking might be the experimental illustration of a property or principle, the rationale might be incomprehensible to a majority of my class, unless an opportunity for studying it were afforded them.

Again, some of my contrivances, which greatly facilitated my experiments, were too complex to be understood without a minuteness of explanation, which, even if it were useful and agreeable to some of my hearers, might be useless and irksome to others; and to such minutiæ I have not deemed it expedient to exact attention.

A chemical class, in a medical school, usually consists of individuals, who differ widely with respect to their taste for chemistry, and in opinion as to the extent to which it may be practicable or expedient for them to learn it. There is also much disparity in the opportunities which they may have enjoyed, of acquiring some knowledge of this science, and of others which are subsidiary to its explanation. Hence a lecturer may expatiate too much for one portion of his auditors, and yet be too concise for another portion. While to the adept he may often appear trite, to the novice he may as often appear abstruse.

Some pupils, actuated by a laudable curiosity, under circumstances permitting its indulgence, may desire an accurate knowledge of the apparatus, by which my experimental illustrations are facilitated: other pupils may feel themselves justified, perhaps necessitated, not to occupy their time with the acquisition of any knowledge which is not indispensable to graduation.

After some years' experience of the difficulties abovementioned, I came to the conclusion, that the time spent in the lecture room might be rendered much more profitable, if students could be previously apprized of the chain of ideas, or the apparatus and experiments, to be subjected to attention at each lecture; especially as the memory might afterwards be refreshed by the same means. In consequence of this conviction, the minutes of my course of instruction were printed; and subsequently a work, comprising engravings and descriptions of the larger portion of such of my apparatus and experiments, as could in this way be advantageously elucidated. Encouraged by the success of my plan, I am now preparing an edition which will be still more extensive. The work thus expanded, I have entitled "A Compendium of the Course of Chemical Instruction in the Medical School," &c.

There will be much matter in the Compendium, respecting which I shall not question candidates at the examination for degrees. With the *essence* of the larger part, I shall undoubtedly expect them to be acquainted; but other portions have been introduced, that I may not be obliged to dwell upon them in my lectures, and that attention to them may be optional on the part of the students. To designate the portion of the work, respecting which candidates for degrees will not be questioned, I have had it printed in a smaller type, excepting where it was too much blended with subjects of primary importance to be separated. I wish it, however, to be understood, that I shall expect attention to the parts thus distinguished, so far as they may be necessary to a comprehension of the rest. Thus, although I do not deem it to be a part of my duty to question a pupil on pneumatics, I shall expect him to understand the influence of atmospheric pressu upon chemical phenomena, and in pneumato-chemic operations.

One great and almost self-evident advantage, resultin from my undertaking, I have yet to mention; I allude to the instruction which students may derive from the Compendium, either before or subsequently to their attendance on my lectures, and especially during the period which intervenes between their first and second course.

PREFACE

TO THE THIRD EDITION.

The health of a portion of my family having rendered it expedient for me to sail for Europe, I was under the necessity of engaging my friend Dr. Bache to superintend the printing of this edition. I regret that I have not been enabled as yet to complete that portion of the work which should comprise Voltaic electricity, galvanism, and electro-magnetism. I hope, however, that, by associating with my book the Treatise of Dr. Turner, of the London University, on the branches thus omitted, the deficiency thus arising will be compensated.

Note.—The additions of Dr. Bache to the text are distinguished by brackets; his notes by the letter B.

CONTENTS.

INTRODUCTION
Definition of Natural Philosophy, Chemistry, and Physiology

PART I.

IMPONDERABLE SUBSTANCES.

SECT. I. Electricity - 5
- Introductory remarks - 5
- Historical sketch - 6
- Experimental illustrations - 9
  - Description of electrical machines
  - Usual means of producing electricity
  - Communication of electricity
  - Different kinds of electricity
  - Means of accumulating electricity
  - Means of detecting and measuring electricity
  - Effects of electricity
  - Additional means of producing electricity
  - Theoretic explanation of electrical phenomena
  - Means of electrifying patients either with sparks or by shocks

II. Caloric
- Expansion
  - Expansion of solids
  - Expansion of liquids - 59
  - Expansion of aëriform fluids - 61
    - Thermometers - 62
- Modification of the effects of caloric by atmospheric pressure 66
- Capacities for heat, or specific heat - 95
- Slow communication of heat, comprising the conducting process and circulation - 96
  - Conducting process in solids - 96
  - Conducting process in liquids - 98
  - Communication of caloric by circulation - 98
- Quick communication of heat, or radiation - 101
- Means of producing heat, or rendering caloric sensible - 104
- Means of producing cold, or rendering caloric latent - 117
- States in which caloric exists in nature - 122

III. Light - 122
- Sources of light - 123
- Heating, illuminating, and chemical properties of the rays 125
- Chemical effects of light - 127
- Polarization of light - 128

PART II.

PONDERABLE SUBSTANCES.

INORGANIC SUBSTANCES - 129

SECT. I. Chemical attraction - 129
- Attraction of aggregation, or cohesion - 130
  - Crystallization - 130
- Chemical affinity, or heterogeneous attraction - 134

II. Definite proportions - 139
- Tables of chemical equivalents - 140

Page
- Atomic theory - 140
- Chemical symbols - 141
- Atomic weights and symbols of the simple substances - 142

Sect. III. Specific gravity - 143
- Method of ascertaining the specific gravity of solids - 145
- Method of ascertaining the specific gravity of liquids - 146
- Method of ascertaining the specific gravity of gaseous substances - 149

IV. Mode of collecting and preserving gases - 150
- Hydro-pneumatic cistern - 150
- Mercurio-pneumatic cistern - 151

INDIVIDUAL INORGANIC SUBSTANCES - 152

SIMPLE INORGANIC SUBSTANCES - 152

BASACIGEN SUBSTANCES - 152

Sect. I. Oxygen - 153

II. Chlorine - 160
- Compounds of chlorine with oxygen - 166
  - Euchlorine, or protoxide of chlorine - 167
  - Chlorous acid - 168
  - Chloric acid - 170
  - Oxychloric or perchloric acid - 170

III. Bromine - 170
- Compounds of bromine with oxygen and chlorine - 172
  - Bromic acid - 172
  - Chloride of bromine - 172

IV. Iodine - 173
- Iodic, hyperiodic, and iodous acid - 176
- Chlorides and bromides of iodine - 177

V. Fluorine - 177

VI. Sulphur - 178
- Compounds of sulphur with oxygen - 180
  - Hyposulphurous acid - 180
  - Sulphurous acid - 180
  - Hyposulphuric acid - 181
  - Sulphuric acid - 182
- Chlorides, bromide, and iodide of sulphur - 183

VII. Selenium - 184
- Compounds of selenium with oxygen - 185

VIII. Tellurium - 186

RADICALS - 186

NON-METALLIC RADICALS - 186

Sect. I. Hydrogen - 187
- Compounds of hydrogen with oxygen - 192
  - Water - 192
  - Deutoxide or bioxide of hydrogen - 200
- Compound of hydrogen with chlorine - 202
  - Chlorohydric or muriatic acid gas - 202
  - Old theory of the nature of chlorine and chlorohydric acid 208
- Compounds of hydrogen with bromine and iodine - 208
  - Bromohydric acid - 209
  - Iodohydric acid - 209
- Compounds of hydrogen with sulphur - 210
  - Sulphydric acid, or sulphuretted hydrogen - 210
  - Polysulphide of hydrogen - 214
- Compounds of hydrogen with selenium and tellurium - 215
  - Selenhydric acid, or selenuretted hydrogen - 215
  - Telluhydric acid, or telluretted hydrogen - 215

II. Nitrogen or azote - 216
- Mechanical compound of nitrogen with oxygen - 218
  - Atmospheric air - 218
- Chemical compounds of nitrogen with oxygen - 225
  - Protoxide of nitrogen, or nitrous oxide - 226
  - Nitric oxide, or nitrous air - 228
  - Hyponitrous acid - 230
  - Nitrous acid - 230
    - Theory of volumes - 234

Page

- Nitric acid 237
  - Nitroso-nitric acid 239
- Some points of chemical theory 243
  - Theories of combustion 243
  - Influence of the habitudes of chemical agents with the Voltaic series on classification and nomenclature 248
  - Origin of the idea of an acidifying principle 251
  - Acidity and alkalinity 252
- Compound of nitrogen with hydrogen 253
  - Ammonia, or the volatile alkali 253
    - Ammonium 259

SECT. III. Phosphorus 261

- Compounds of phosphorus with oxygen 266
  - Oxide of phosphorus 266
  - Hypophosphorous acid 267
  - Phosphorous acid 267
  - Phosphoric acid 267
- Chlorides of phosphorus 268
- Bromides and iodides of phosphorus 269
- Sulphides and selenides of phosphorus 269
- Compounds of phosphorus with hydrogen 269
  - Protophosphuretted hydrogen 269
  - Perphosphuretted hydrogen 269

IV. Carbon 271

- Compounds of carbon with oxygen 275
  - Carbonic oxide 276
  - Carbonic acid 277
  - Oxalic acid 281
  - Mellitic acid 282
  - Croconic acid 282
- Compounds of carbon with oxygen and chlorine 283
  - Chloral 283
  - Chloroxycarbonic acid 283
- Chlorides of carbon 283
- Bromide of carbon 284
- Iodides of carbon 284
- Sulphocarbonic acid, or bisulphide of carbon 284
- Xanthohydric acid and xanthogen 284
- Compounds of carbon with hydrogen 285
  - Light carburetted hydrogen, or fire damp 287
    - Safety lamp 288
  - Deutocarbohydrogen, or olefiant gas 289
  - Other varieties of carbohydrogen 290
    - Tetartocarbohydrogen, or etherine 291
    - Hexacarbohydrogen 291
  - Bicarburet of hydrogen 291
  - Naphthaline 291
- Compounds of carbon with chlorine and hydrogen 291
  - Bichlorine ether 291
- Compound of carbon with nitrogen 291
  - Bicarburet of nitrogen, or cyanogen 291
    - Nomenclature of the compounds of cyanogen 293
    - Cyanic, cyanuric, and fulminic acid 294
    - Chlorides, bromides, and iodides of cyanogen 295
    - Sulphocyanogen 295
      - Sulphocyanhydric acid 296
    - Cyanhydric or prussic acid 296

V. Boron 299

- Compound of boron with oxygen 300
  - Boric or boracic acid 300
- Chloride of boron 301

VI. Silicon 301

- Compound of silicon with oxygen 303
  - Silica, or silicic acid 303
    - Glass 304
- Compounds of fluorine with hydrogen, boron, and silicon 305

Page
Fluohydric acid 305
Fluoboric acid 306
Fluosilicic acid 307
SECT. VII. Zirconion 309
Compound of zirconion with oxygen 310
METALLIC RADICALS 310
METALS OF THE EARTHS PROPER 316
SECT. I. Aluminium 316
Alumina 317
Chloride of aluminium 319
II. Glucinium 320
Glucina 320
III. Yttrium 320
Yttria 320
IV. Thorium 321
Thorina 321
METALS OF THE ALKALINE EARTHS 321
SECT. I. Magnesium 322
Magnesia 322
II. Calcium 323
Lime 323
Peroxide or bioxide of calcium 325
III. Barium 325
Baryta 326
IV. Strontium 327
Strontia 327
Peroxides or bioxides of barium and strontium 328
METALS OF THE ALKALIES, OR ALKALIFIABLE METALS 329
SECT. I. Potassium 329
II. Sodium 330
Potash or potassa, and soda 330
Peroxides and suboxides of potassium and sodium 332
III. Lithium 334
Lithia 334
Reaction of chlorine, bromine, iodine, fluorine, and cyanogen, with the metals of the earths and alkalies 335
Reaction of sulphur, selenium, and tellurium, with the metals of the earths and alkalies 338
METALS PROPER 340
SECT. I. Gold 340
Compounds of gold with oxygen 341
Compounds of gold with the halogen class 342
Compounds of gold with sulphur 343
II. Platinum 344
Compounds of platinum with oxygen 345
Compounds of platinum with the halogen class 346
Compounds of platinum with sulphur 346
Power of platinum and other metals in a divided form to induce chemical reaction 346
III. Silver 348
Compounds of silver with oxygen 350
Compounds of silver with the halogen class 351
Compounds of silver with sulphur 351
IV. Mercury 352
Compounds of mercury with oxygen 353
Reaction of acids with mercury and its oxides 354
Chlorides of mercury 356
Bromides, iodides, fluorides, and cyanides of mercury 359
Compounds of mercury with sulphur 359
Phosphurets of mercury 360
Alloys of mercury, or amalgams 360
V. Copper 362
Compounds of copper with oxygen 364
Compounds of the oxides of copper with acetic acid 366
Compounds of copper with the halogen class 366
Compounds of copper with sulphur and selenium 367

Page
Sect. VI. Lead 368
Compounds of lead with oxygen 368
Compounds of the protoxide of lead with acetic acid 370
Carbonate of lead 371
Compounds of lead with the halogen class 371
Compounds of lead with sulphur and selenium 372
VII. Tin 373
Compounds of tin with oxygen 373
Compounds of tin with the halogen class 374
Compounds of tin with sulphur and selenium 375
VIII. Bismuth 376
Compounds of bismuth with oxygen 377
Compounds of bismuth with the halogen class 377
Compounds of bismuth with sulphur and selenium 378
IX. Iron 378
Compounds of iron with carbon, boron, silicon, and phosphorus 380
Compounds of iron with oxygen 381
Reaction of iron with acids 383
Compounds of iron with the halogen class 383
Compounds of iron with sulphur and selenium 385
X. Zinc 386
Compounds of zinc with oxygen 386
Compounds of zinc with the halogen class 388
Compounds of zinc with sulphur and selenium 388
XI. Arsenic 389
Compounds of arsenic with oxygen 390
Compounds of arsenic with the halogen class 393
Compounds of arsenic with sulphur and selenium 393
Compounds of arsenic with phosphorus and hydrogen 394
Means of detecting arsenic in cases where poisoning is suspected by it 395
XII. Antimony 398
Compounds of antimony with oxygen 400
Compounds of antimony with the halogen class 401
Compounds of antimony with sulphur and selenium 402
Tartrate of potash and antimony, or tartar emetic 404
XIII. Metals proper of minor importance 406
Palladium 406
Rhodium 407
Iridium 407
Osmium 407
Nickel 408
Cadmium 408
Chromium 408
Cobalt 410
Columbium 410
Manganese 410
Molybdenum 411
Titanium 411
Tungsten 411
Uranium 411
Cerium 412
Vanadium 412
Salts 412
Sect. I. Oxysalts 414
Chlorates 414
Oxychlorates 416
Chlorites 416
Nitrates 418
Nitrites and hyponitrites 418
Sulphates 419
Hyposulphates, sulphites, and hyposulphites 419
Seleniates 420
Phosphates 420
Phosphites 420

Page
Carbonates - - - - - - - - - 420
Borates - - - - - - - - - 421
Silicates - - - - - - - - - 421
Cyanates and fulminates - - - - - - 421
Double oxysalts - - - - - - - - 421
SECT. II. Sulphosalts - - - - - - - - - 422
III. Selenisalts and tellurisalts - - - - - - 423
IV. Chlorosalts, bromosalts, iodosalts, and fluosalts - - 423
V. Cyanosalts - - - - - - - - - 424
ORGANIC SUBSTANCES - - - - - - - - - - - 425
VEGETABLE SUBSTANCES - - - - - - - - - - 425
Mode in which the ultimate ponderable elements of organic substances are associated - - - - - 426
Influence of heat upon vegetables - - - - - 427
Effects upon vegetable matter of chlorine, bromine, iodine, &c. 428
Influence of the proportions of the ultimate elements upon the qualities of the substances which they constitute 429
PROXIMATE VEGETABLE SUBSTANCES - - - - - - 430
SECT. I. Vegetable substances which are neither acid, alkaline, oily, resinous, nor volatile - - - - - - - 430
Gum and mucilage - - - - - - - 430
Sugar - - - - - - - - - 432
Fecula or starch - - - - - - - - 433
Conversion of fecula into dextrine and raisin sugar - 434
Gluten and vegetable albumen - - - - - 436
Indigo and indigogene - - - - - - 438
Caoutchouc or gum elastic - - - - - - 438
Lignin - - - - - - - - - 440
Cork - - - - - - - - - 440
II. Oils - - - - - - - - - - 441
Fixed oils - - - - - - - - - 441
Wax - - - - - - - - - 443
Volatile oils - - - - - - - - - 443
Camphor - - - - - - - - - 445
Paraffine and eupione - - - - - - 446
Kreosote - - - - - - - - - 446
III. Resins - - - - - - - - - - 447
Acid resins - - - - - - - - - 448
Basic resins - - - - - - - - - 448
IV. Gum-resins - - - - - - - - - 449
Opium - - - - - - - - - 449
V. Naphtha, petroleum, bitumen, amber, and mineral coal - 450
VI. Vegetable acids - - - - - - - - - 451
Acetic acid - - - - - - - - - 451
Pyroligneous acid - - - - - - - - 452
Citric and malic acid - - - - - - 453
Tartaric acid - - - - - - - - 454
Tannic acid, or tannin - - - - - - 455
Gallic acid - - - - - - - - - 456
Succinic acid - - - - - - - - 456
Benzoic acid - - - - - - - - 456
Benzule - - - - - - - - - 457
Meconic acid - - - - - - - - 457
Kinic acid - - - - - - - - - 458
Valerianic acid - - - - - - - - 459
Crotonic acid - - - - - - - - 459
Cevadic acid - - - - - - - - 459
VII. Vegetable alkalies - - - - - - - - 459
Natural state and mode of preparation of the vegetable alkalies - - - - - - - 461
Chemical characters of the vegetable alkalies - - - 461
Constitution of the vegetable alkalies - - - - 463
Morphia - - - - - - - - - 464
Paramorphia and pseudomorphia - - - - - 465
Codeia - - - - - - - - - 465
Narcotina - - - - - - - - - 465

Page

Narceia - 465
Cinchonia and quinia - 466
Aricina - 467
Strychnia - 467
Brucia - 467
Delphia - 468
Veratria - 468
Sabadillia - 468
Emetia - 468
Solania - 469
Atropia - 469
Menispermia - 469
Melamia and ammelia - 469
VIII. Doubtful vegetable alkalies - 470
Aconitin - 470
Daturin - 470
Hyoscyamin - 470
Corydalin - 470
Curarin - 470
Nicotin - 470
Colchicin - 470
IX. Vinous Fermentation - 470
Yeast or ferment - 471
Alcohol - 472
X. Ethers - 473
Hydrated organic acid ethers - 475
Hydric ether, commonly called sulphuric ether - 475
Sulphate of etherine, or oil of wine - 477
Sulphurous ether - 478
Hoffmann's anodyne - 478
Chlorohydric or muriatic ether - 480
Iodohydric and bromohydric ether - 480
Ethereal compounds of etherine with halogen bodies - 480
Nitric ether - 481
Thialic ether, and mercaptan and mercaptum - 483
Additional compounds of etherine - 484
Pyroacetic spirit - 485
Pyroxylic spirit - 485
XI. Acetous fermentation - 486
ANIMAL SUBSTANCES - 487
Effects of ignition on animal matter - 487
Peculiarities in the composition of animal matter - 488
PROXIMATE ANIMAL SUBSTANCES - 488
SECT. I. Animal substances which are neither resinous, oily, nor acid - 488
Fibrin - 488
Albumen - 489
Gelatin - 491
Caseum - 492
Cantharidin - 493
Mucus - 494
Urea, or the crystallizable matter of urine - 494
Animal sugar - 495
II. Animal resins - 496
Resin of bile - 496
Cerumen, or ear-wax - 496
Ambergris - 496
Castor - 497
III. Animal oils or fats - 497
Butyrin, phocenin and hircin - 498
Glycerine, or the sweet principle of oils - 498
Adipocire - 498
IV. Animal acids - 499
Uric acid - 500
Purpuric acid - 501
Rosacic acid - 501

Page
Lactic acid - 502
Formic acid - 502
COMPLEX ANIMAL LIQUIDS AND SOLIDS - 503
SECT. I. Animal liquids - 503
Blood - 503
Chyle - 505
Respiration - 506
Animal secretions - 510
Gastric juice - 510
Milk - 511
Urine - 512
Bile - 512
Sweat - 513
II. Animal solids - 513
Urinary calculi - 513
Arthritic concretions - 515
Skin - 515
Bones - 515
Brain - 516

PUTREFACTIVE FERMENTATION - 516
CONCLUSION - 518

ERRATUM.

Page 416, line 23, for "and ammonia, at the temperature of 59°. Oxychlorate" &c., *read*, and ammonia. At the temperature of 59°, oxychlorate, &c.

DEFINITIONS OF CHEMISTRY.

It is natural that a person whose attention may be directed to chemistry, should inquire of what does it treat, or how is it to be defined or distinguished from other sciences?

Agreeably to the definition given in the second page of the Compendium, chemistry treats of those phenomena and operations of nature which arise from reaction between inorganic particles.

I subjoin several other definitions from some of the most celebrated modern writers on chemistry.

Thomson defines chemistry to be "the science which treats of those events or changes in natural bodies, which are not accompanied by sensible motions."

Henry conceives that "it may be defined, the science which investigates the composition of material substances, and the permanent changes of constitution, which their mutual actions produce."

According to *Murray*, "it is the science which investigates the combinations of matter, and the laws of those general forces, by which these combinations are established and subverted."

Brande alleges "that it is the object of chemistry to investigate all changes in the constitution of matter, whether effected by heat, mixture, or other means."

According to *Ure*, "chemistry may be defined that science, the object of which is to discover and explain the changes of composition that occur among the integrant and constituent parts of different bodies."

The definition given by *Berzelius* is as follows:—"Chemistry is the science which makes known the composition of bodies, and the manner in which they comport with each other."

COMPENDIUM

OF

CHEMICAL INSTRUCTION,

&c.

INTRODUCTION.

The phenomena and operations of the material world appear to be dependent on certain properties in the particles or masses of matter which enable them to exercise a reciprocal influence. Without this reciprocal action, which I would prefer to call reaction,* every particle or mass would be as if no other existed, and could itself have no efficient existence.

The reciprocal action or reaction, thus inferred to exist, may be distinguished as taking place between masses, between a mass and particles, and between particles only.

Reaction between masses† is sublimely exemplified in the solar system, by that attraction between the sun and planets, by which they are made to revolve in their orbits.

Reaction between a mass and particles is exemplified by the reflection, refraction, and polarization of light; as by the moon, the rainbow, the Iceland spar.

Reaction between particles is exemplified by a fire, or the explosion of gunpowder.

Definition of Natural Philosophy, Chemistry, and Physiology.

Natural Philosophy, in its most extensive sense, treats of physical reaction generally. In its more limited and usual acceptation, it treats of those phenomena and operations of nature, which arise from reaction between masses, or between a mass and particles.

---

* In Mechanics, action is said to produce reaction; but in the case of an innate property, which mutually causes different portions of matter to be self attractive, or repellent, it is impossible to distinguish the agent from the reagent. From our first acquaintance with any bodies so situated, they may be said mutually to react, or to exercise reaction.

† By the word mass, I mean a congeries of particles capable of producing some effect collectively, to which severally they would be incompetent.

Chemistry treats of the phenomena and operations of nature, which arise from the reaction between the particles of inorganic matter.

Physiology treats of the phenomena and operations, which arise from the reaction of the masses or atoms of organic or living bodies.

OF CHEMICAL REACTION.

Reaction between particles, or chemical reaction, is distinguished into repulsive reaction or repulsion, and attractive reaction or attraction.

OF REPULSIVE REACTION OR REPULSION.

A Priori Proofs that there must be a Matter in which Repulsion exists as an Inherent Property.

Matter may be defined to be that which has properties. We know nothing of matter directly. It is only with its properties that we have a direct acquaintance. It is from our perception of matter, through the powers or properties by which it affects our senses, that we become confident in its existence.

The existence of repulsion and attraction is as evident as that of the matter which, in obedience to their successive predominancy, may be seen either to cohere, as in solids, with great tenacity, or to fly apart with explosive violence in the state of a vapour. The existence of repulsion and attraction being proved, it must be admitted that they are properties of matter; since the existence of a property, independently of matter, is inconceivable. But being of a nature to counteract each other, the repellent and attractive powers cannot coexist in particles of the same kind, and consequently must belong to particles of different kinds. There must, therefore, be a matter endowed with repulsion, distinct from that which is endowed with attraction.

I conceive that the phenomena of chemistry demonstrate that there are at least the three following properties, which, from their obvious incompatibility, cannot belong to the same elementary particles.

1. An innate property of reciprocal attraction.

2. An innate property of counteracting attraction directly, by imparting reciprocal repulsion.

3. An innate property of imparting an attraction, variable in its force, and limited and contingent in its duration.

I presume that there must be at least three different kinds of matter, to each of which, one of the properties thus specified innately appertains.

The permanent and unvarying attractive power is exemplified by gravitation, and, as modified by circumstances, by tenacity, or cohesion.

It resides undoubtedly in every kind of matter endowed with weight, and consequently in all that is considered as material by the mass of mankind.

It must likewise act between each of those imponderable principles which I am about to mention, and all other matter, whether ponderable or imponderable.

The power of imparting reciprocal repulsion to ponderable matter is supposed by chemists generally to belong tō certain imponderable material reciprocally repulsive particles, constituting the cause of heat, called caloric.

The power of indirectly counteracting attraction, and substituting for it a contingent and variable attraction, appears to belong to electricity. Light also appears to exercise a modifying influence.

Thus we have reason to infer the existence of at least three imponderable substances—electricity, caloric, and light—each consisting of particles reciprocally repulsive, yet attractive of other matter, and probably more or less attractive of each other.

[The imponderable substances just named will be treated of in the three following sections, and will constitute the first part of the work. Ponderable substances will afterwards be considered, and form the second part.]

PART I.

IMPONDERABLE SUBSTANCES.

SECTION I.

ELECTRICITY.

INTRODUCTORY REMARKS.

Both the theory and nomenclature of chemical science are at present grounded upon the electrical habitudes of chemical agents. Under these circumstances, a knowledge of mechanical and galvanic electricity is of fundamental importance; and to impart this knowledge, where it has not to a sufficient extent been made part of the student's previous education, should be a preliminary object. I, therefore, consider it expedient to place the section on electricity at the beginning of the Compendium, instead of at the end, where it has heretofore stood.

There are additional reasons for giving precedency to electricity. There is no other science which stands so much by itself, or which requires so little preliminary knowledge to render it intelligible. This remark applies more particularly to that portion of it which is necessarily first treated of, being usually designated as mechanical, in contradistinction to voltaic electricity.

I shall assign to caloric the second place in my work, and to light, the third. Thus the illustrations of the three imponderable agents, whose existence is generally admitted by chemists, will be exhibited in immediate succession, and the diversity of their features rendered more striking by their proximity.

HISTORICAL SKETCH.

An attractive power is acquired by resins, sulphur, glass, and a variety of other substances, when rubbed; and if the masses, thus excited, be sufficiently large, the phenomena of light, of mechanical concussion, and ignition, may result, and even a feeble imitation of thunder and lightning.

As it was in amber, in Greek called *Electron*, that the attractive power, arising from friction, was first observed, the principle to which it was ascribed was called electricity, and all substances, in which it could be produced, electrics.

We are informed that Thales of Miletus, who flourished six hundred years before Christ, was so much struck with this effect of the friction of amber, as to imagine that it might be endowed with animation. Subsequently, it was ascertained that the attractive power, which had been observed in amber when subjected to friction, might be produced, by the same means, in other resinous substances, and in the tourmaline, or lyncurium as it was then called, by exposure to heat.

No further progress was effected in electrical knowledge until the seventeenth century, when, after considerable additions had been made to the catalogue of electrics by Gilbert and Boyle, Otho Guericke discovered that light and sound might result from electric excitement. His observations were made by means of a globe of sulphur, cast in a glass vessel which was fractured to extricate the casting. Little was it suspected by the ingenious operator, that the glass globe, thus broken, would have answered better for the purpose in view than the globe of sulphur, in the moulding of which it was sacrificed.

The discovery of the usefulness of glass as a mean of producing electricity appears to have been made by Hawkesbee, who wrote in 1709. To Grey, who followed Hawkesbee, we owe the remark that the electrical excitement of glass and other electrics was communicable to other bodies when insulated, not only by direct contact, but by wires or threads of great length; and by this electrician, in conjunction with another named Wheeler, it was first observed that this property of conducting the electric virtue, while belonging to flax or hemp, did not belong to silk; also, that, by the class of bodies in which electricity can be excited, it cannot be conducted; whilst in those by which it may be conducted, it cannot be excited. Thus were two classes of bodies distinguished; one as electrics, or non-conductors, the other as non-electrics, or conductors.

It was ascertained, however, that a conductor, if supported by a non-conductor, might receive the electric virtue from an excited electric. A conductor, so supported, was said to be *insulated*.

Du Faye soon after ascertained the important truth that there are two kinds of electrical excitement. One of these, being observed in glass, was called vitreous; and the other, resinous, because observed in resins. By the communication of either species of excitement, light bodies were made to separate from each other; but the bodies excited by means of resins were attracted by such as were excited by means of glass; and when these opposite excitements were made, in due proportion, in different insulated conductors, on bringing the conductors together, a neutralization, and of course an apparent annihilation, of the electricity in both was the consequence.

The means of collecting the electric fluid were soon after much improved in Germany; where sparks sufficient to kill birds, and ignite spirits and other inflammable matter were produced by the joint influence of several globes simultaneously excited.

In the year 1746, the Leyden phial was invented. Cuneus and Mushenbrœck, attempting to charge the water contained in a phial with electricity, a shock was experienced by Cuneus, who happened to touch the conductor with one hand, while grasping the phial with the other.

This phenomenon was soon after explained by Franklin. He had ascertained that, whenever either kind of electricity is communicated by friction to one body, the other kind will be created in the mass by means of which the friction is effected, provided it be insulated.

When a glass is rubbed by the hand, it takes electricity from the hand, and from the person to whom it belongs. If standing on a non-conductor, the person will be electrified, at the same time that the glass which he rubs may, by contact, excite another body; but, then, the electricity of the person who rubs the tube, and that of the body to which he presents the tube are of opposite kinds; the former being the resinous, the latter the vitreous electricity of Du Faye. A stick of resin would cause the opposite result, producing vitreous electricity in the person rubbing it, and resinous in a body touching the resin, subsequently to its exposure to friction.

These phenomena were thus accounted for by Franklin. Some bodies by friction (glass for instance) acquire additional power to hold the electric fluid, and hence draw it from the conducting body rubbing them, and give up the excess to any adjoining conductor, when the friction ceases. Resins, on the other hand, have their capacity for the electric fluid lessened by rubbing, and hence, while subjected to this process, give it out to the rubber, and afterwards draw on any adjoining body to supply their deficiency. Glass and resin, therefore, produce both kinds of electricity, which are merely the result of an accumulation, or deficiency, in an insulated body, of a fluid which pervades all nature. A conductor, charged in either way, will produce an electrical current when presented to other bodies in connexion with the earth. In the one case, electricity will flow into the conductor; in the other case, it will flow out of it.

Franklin, also, discovered that, when an electrical stream is directed into a phial, situated like that of Cuneus, there is, at the same time, a stream proceeding from the outside; so that, in proportion as one surface gains, the other loses; and, accordingly, in a charged phial, one surface will be found vitreously, or redundantly, excited, the other, resinously, or deficiently; and a light body, after touching either surface, will be repelled by it, and attracted by the other.

He inferred that there was only one electric fluid, to different states of which, the names of vitreous and resinous electricity had been erroneously applied. The latter he called negative, the former positive electricity.

Franklin afterwards identified lightning with electricity, by drawing this fluid from the clouds by means of a kite; availing himself of a contrivance, which had previously been appropriated to juvenile recreation, to make a most sublime and useful discovery.

ELECTRICITY EXPERIMENTALLY ILLUSTRATED.

The ingenuity of practical electricians has given rise to a great number of contrivances, which amuse the spectator by producing some striking movements, or changes, consequent to electrical excitement. The various apparatus thus originated has been treated too much as a mean merely of affording amusement. There is not a modification of electrical apparatus which is not dependent, for its appropriate effect, upon some property of the electric fluid, which it may consequently serve to illustrate.

I shall endeavour to use the various contrivances, above alluded to, in such order and with such associations, as to make their employment contribute both to the amusement and instruction of my pupils.*

ORDER TO BE PURSUED IN THE EXPERIMENTAL ILLUSTRATION OF ELECTRICITY.

Description of Electrical Machines.—Usual means of producing Electricity.—Communication of Electricity.—Different kinds of Electricity.—Means of accumulating Electricity.—Means of detecting Electricity.—Effects of Electricity.—Additional means of producing Electricity.—Theoretic explanation of Electrical Phenomena.—Means of Electrifying Patients either with sparks or by shocks.

GENERIC DESCRIPTION OF THE ELECTRICAL MACHINE.

A description of the electrical machine should be applicable to every apparatus which bears the name. I am unacquainted with any apparatus, designated as an electrical machine, which does not consist of an electric, so situated as to be conveniently subjected to a friction calculated to produce electric excitement, one or more collectors, attached to a prime conductor properly insulated, and one, or more cushions, for rubbing the electric. The cushions, in the more perfect forms of the machine, are associated with another insulated conductor.

---

* The student who aims merely at that general knowledge which may be required at his examination for a degree, is not obliged to study all the matter comprised in my text book. So far indeed am I from exacting attention to every topic thus comprised, that my motive for printing many engravings, descriptions, and some abstruse rationales, is to obviate the necessity of occupying much time with them during my lectures. Yet there can be no doubt that a student, who will, before or during the course, study them attentively, will be much better prepared to understand, with accuracy, the general truths which my apparatus is intended to illustrate; and it is but right that those who prefer this accuracy of knowledge, from taste or ambition to excel, should have every facility afforded to them in making the effort.

I shall endeavour to indicate the relative importance of the matter to the medical candidate by the size of the type.

Experience has shown that, of all the electrics, glass is the best for the construction of electrical machines; and of all the possible forms, only two are much in use, those of the cylinder and of the circular plate. In either case, the friction is produced by the rotation of a shaft, occupying the axis of the cylinder, or plate, and fastened by screws or cement. The shaft or axis, being secured in one or more collars like the mandril of a lathe, is turned by a winch, or by a band and wheels, which are so proportioned and arranged as to quicken the motion. In cylinder machines, it is usual, besides the cushion, to have a silken flap, of which one border is sewed to the edge of the cushion, so that it may extend from the cushion, till the other border approximates the collectors.

Plate machines are sometimes furnished with silk flaps.

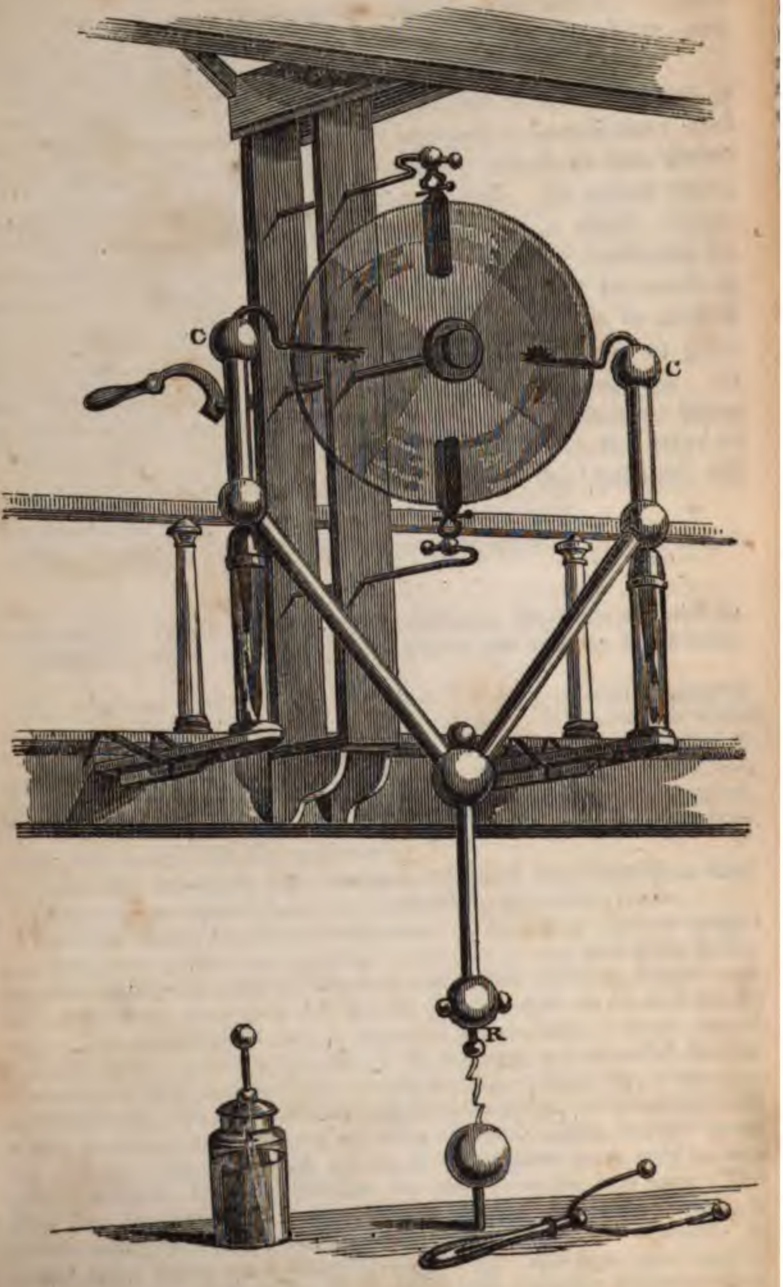
1. *Description of an Electrical Plate Machine, the Plate mounted horizontally, and so as to show both Negative and Positive Electricity.*

The power of electrical plate machines has been generally admitted to be greater than that of machines with cylinders. The objection to the former has been the difficulty of insulating the cushions, so as to display the negative electricity. Excepting the plate machine contrived by Van Marum, I have read of none in which this difficulty has been surmounted. It is still insisted upon by respectable electricians, as if it had not been sufficiently removed by his contrivance.

I shall now describe a plate machine, by which both electricities may be produced, and which I have used successfully for twelve years.

The Plate (thirty-five inches in diameter) is supported upon an upright iron bar, about an inch in diameter, covered by a very stout glass cylinder, four inches and a half in diameter, and sixteen inches in height, open only at the base, through which the bar is introduced, so as to form its axis. The summit of the bar is furnished with a block of wood, turned to fit the cavity, formed at the apex of the cylinder, and cemented therein. The external apex of the cylinder is cemented into a brass cap, which carries the plate. The glass cylinder is liable to no strain. It is only pressed where it is interposed between the block of wood within, and the brass cap without. The remaining portion of the cylinder bears only its own weight, while it effectually insulates the plate from the iron axis. The brass cap is surmounted by a screw and flange, by means of which, a corresponding nut, and disks of mahogany, the plate is fastened. A square table serves as a basis for the whole. The iron axis, passing through the top of the table, is furnished with a wooden wheel of about

Large Electrical Plate Machine.



twenty inches in diameter, and terminates below this wheel in a brass step, supported on a cross of wood, which ties the legs of the table diagonally together. The wheel is grooved and made to revolve by a band, which proceeds from around a vertical wheel outside of the table. This external wheel has two handles, by means either of one or both of which it may be turned. It is supported on two strips of wood, which, by appropriate screws, may be protruded, lengthwise, from cases, which confine them from moving in any other direction. Consequently, the distance between the wheels may be varied at pleasure, and the tension of the band adjusted.

Nearly the same mode of insulation and support, which is used for the plate, is used in the case of the conductors. These consist, severally, of arched tubes of brass, of about an inch and a quarter in diameter, which pass over the plate from one side of it to the other, so as to be at right angles to, and at a due distance from, each other. They are terminated by brass balls and caps, which last are cemented on glass cylinders of the same dimensions nearly, as that which supports the plate. The glass cylinders are suspended upon wooden axes, surmounted by plugs of cork, turned accurately to fit the space which they occupy. The cylinders are surrounded and secured below, by wooden rings screwed to the table. In this way the conductors are effectually insulated, while the principal strain is borne by the wooden axes.

2. *Electrical Machine, with a Plate four feet in diameter.*

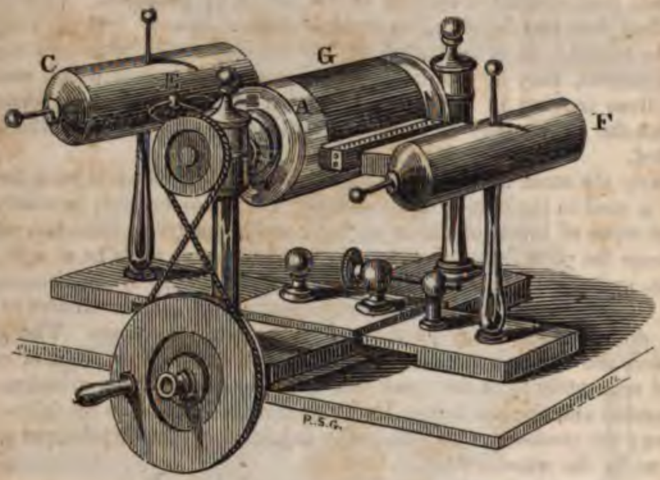
The opposite engraving represents a machine, which I have recently constructed so as to be permanently affixed to the canopy over the hearth of my lecture room. See plate at the commencement of this volume.

This situation I have found convenient even beyond my expectations; as the machine is always at hand, yet never in the way. In lecturing, with the aid of a machine on the same level with the lecturer, one of two inconveniences is inevitable. Either the machine will occasionally be between him and a portion of the audience, or he must be between a portion of the audience and the machine. Situated like that which I am about to describe, a machine can neither hide the lecturer, nor be hidden by him. With all its power at his command while kept in motion by an assistant, he has no part of it to reach or to handle besides the knob and sliding rod of the conductor, which is in the most convenient situation.

The object of this machine being to obtain a command of much electrical power for experiments, in which such power is requisite, it was not deemed necessary to insulate the cushions and the axis, as in the horizontal plate machine.

The prime conductor is insulated upon the same plan, as those described in the last article. At C C are the collectors. R represents a sliding rod, which may be drawn out to such an extent, as to be brought in contact with any apparatus placed under it upon the table.

3. *Engraving and Description of an Electrical Cylinder Machine.*



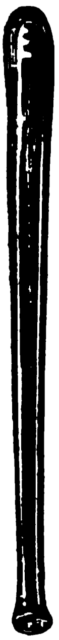
A, the glass cylinder—C, the positive, or prime conductor, supported on a glass pillar—E, the collector with its points so projecting as to be quite near to the cylinder. The negative conductor, F, is also upheld by a glass pillar, supporting the rubber or cushion to which the silk flap, G, is attached. By means of a set screw, the larger wheel may be made more or less remote from the smaller one, so as to adjust the tension of the band by which motion is communicated to the one from the other.

The former being turned by the winch, causes the smaller one to revolve, and of course the cylinder to the axis of which it is affixed. The revolution of the cylinder while the cushion is pressed against it by a suitable spring, causes the friction which is requisite to excite each portion of the cylinder as it successively passes the cushion. Each of the conductors is furnished with projecting brass knobs, whence to take sparks.

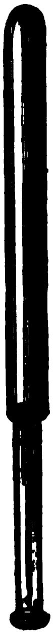
USUAL MEANS OF PRODUCING ELECTRICITY.

It has been stated, in the preceding remarks, that an attractive power is acquired by resins, sulphur, glass, and a variety of other substances when rubbed:—also, that bodies, susceptible of this species of excitement, are called electrics, and the principle, on which it is supposed to be dependent, is called electricity.

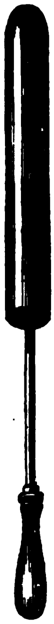
A



B



C



A represents a glass tube.

B, a similar tube coated with shell lac, or sealing wax.

C, an iron rod, furnished at one end with a wooden handle, while throughout the greater part of its length, it forms the axis of a cylinder of sulphur.

Either of the instruments thus constituted, being rubbed, either with a silk handkerchief, a cat skin, or a leather coated with amalgam, will become sufficiently excited to attract leaf metal, and produce other indications of electricity. The amalgam and leather can only be used advantageously with the glass.

4. *Experimental Illustrations.*

Friction of amber, glass, resin, sulphur. Large glass tubes rubbed—also, cylinders of sulphur and of resin. Thin metallic leaves attracted, at a considerable distance, either by the glass, the sulphur, or the resin.

Electrical machines put in operation.

COMMUNICATION OF ELECTRICITY.

The electric virtue cannot pass from one part of an electric which is excited to another without extraneous aid; nor can it pass off, from one electric, through any other. Hence these substances are called non-conductors. Through metals, on the other hand, it escapes instantaneously. It passes with ease through flax or hemp, but not through silk. Water it pervades with great facility, or any thing which contains moisture.

Substances which are thus capable of transmitting electricity are called conductors, and are divided into perfect and imperfect conductors. The metals are the only perfect conductors. All other conductors are imperfect; and, at the head of this class, is charcoal, as being the best conductor of electricity next to the metals.

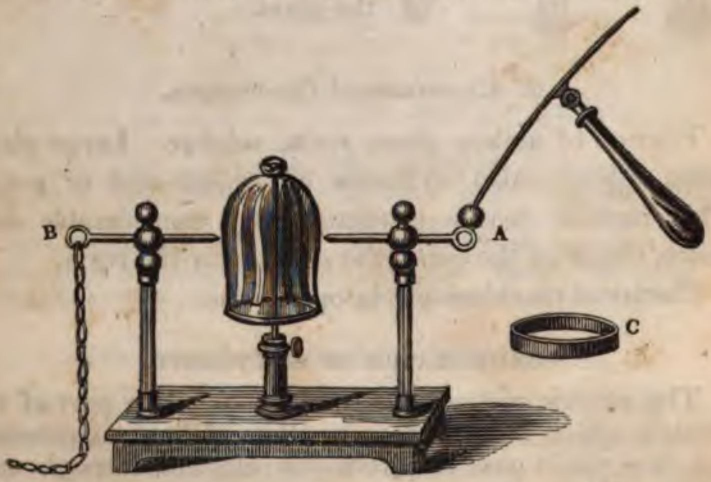
Experimental Proofs that Electricity does not pass from one part of an Electric to another, through, or by means of, an Electric.

5. *An Experimental Illustration.*

One part of a cylinder of sulphur, or of glass being excited by friction, so as to attract light bodies; another part, not being rubbed, is not found to attract them.

6. *Peale's Experiment.*

Among the multitude of electrical contrivances already alluded to, that which we owe, as I believe, to Mr. Franklin Peale, deserves more than ordinary praise for its simplicity of construction, and beauty of effect. One modification of Peale's apparatus is represented by the following engraving, which I shall proceed to explain.



A bell glass is balanced upon a pivot reaching internally to the apex, between wires supported on glass pillars. One wire, A, communicating with the positive, the other, B, with the negative pole of the machine. Under these circumstances, if the machine be put in operation, the portion of the glass next to the wire, A, becomes positively excited, that near B, negatively excited. Consequently, agreeably to the general law that bodies similarly electrified separate, those dissimilarly electrified approach; each excited portion of the glass will move away from the wire similarly excited, and will seek that which is differently excited. Thus the excitements changing the situations of the excited parts, and their exchange of situation reversing their excitements, a rapid movement must ensue, in the only mode in which it can take place freely; I mean that of a rotation on the pivot.

The bell is ornamented by strips of gilt paper, which renders the motion more sensible to the eye; but no coating is requisite to the appropriate effect. A bare bell glass is sufficient.

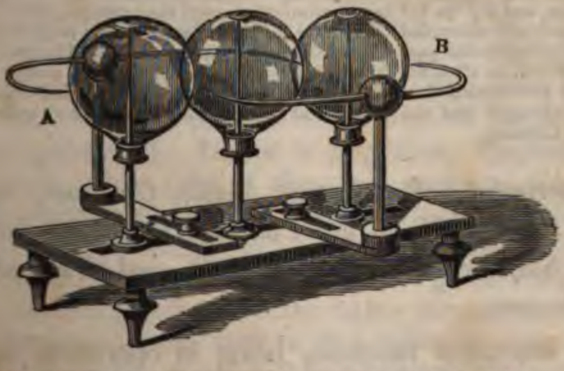
If the metallic band, C, be made to encompass the bell glass, it will be found incapable of receiving any motion from the electrical excitement. In fact, the electric fluid will be seen passing into it on one side, and passing out of it simultaneously on the other side; proving that it cannot, under these circumstances, retain any excitement, in consequence of the conducting power of the metallic band.

Mr. Peale's experiment was performed by means of a globular glass vessel with a short neck, or perforation for the admission of the pivot wire. The pupil will perceive that I have availed myself of this apparatus, to show that the electrical excitement communicated to one part of a non-conductor, does not extend itself to others; and that consequently in different parts of the same non-conducting mass, opposite kinds of electrical excitement may be produced. It is owing to this property, that the glass bell is put into motion. The electric fluid, being unable to pass along the glass, in its efforts to seek an equilibrium, moves the glass along with it, in consequence of an attraction arising between each wire, and that part of the glass which has a different excitement.

That the phenomenon owes its existence to the non-conducting power of the glass, is shown by encircling it with a metallic band, through which the fluid passes from one side of the glass to the other with perfect ease. Under these circumstances, that diversity of excitement, which would cause the rotatory motion, cannot arise.

7. *Modification of Peale's Experiment.*

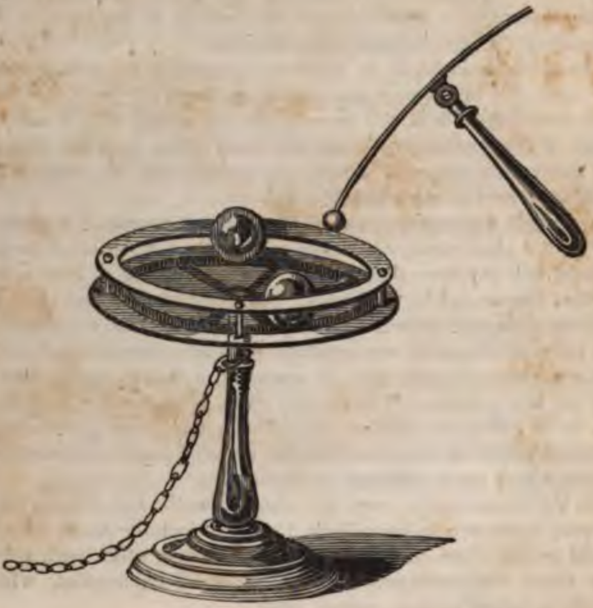
The following figure shows a modification of Peale's apparatus, by which I have contrived to put three globes in motion.



The arched wires, A, B, being severally connected with the different conductors of an electrical machine, cause opposite states of excitement upon the surfaces of the globes, in the neighbourhood of their pointed terminations. A revolution of the excited surfaces, arising from the attraction of the differently excited wires, consequently ensues, in a manner analogous to that already described in the case of the bell glass above mentioned.

8. *Additional Illustration.*

The principle explained by the preceding experiment receives another amusing illustration by means of an experiment, for the explanation of which this engraving is intended.



A glass ball is supported on a glass plate. On the plate, strips of tin foil are so pasted, as to form a broad circle or border near the margin of the plate, and four radii to that circle. There is likewise a flat brass ring, supported and of course insulated by glass pillars, so as to have its inner edge immediately over the exterior edge of the foil.

The brass ring being in communication with the prime conductor of the machine in operation, and the tin foil in communication with the cushions, the ring and foil will be oppositely electrified. The ball, being attracted by the ring, becomes positively electrified in the part which comes in contact with it. The part thus electrified will then be attracted by the foil, and communicating its charge, return to the ring to undergo another change. Different parts in succession undergo these electrical changes, and the consequent movements, which are of course complicated and amusing.

9. *Experimental Proofs that Metals, Charcoal, Moisture, and Flax or Hemp are Conductors of Electricity, and that Sulphur, Resins, Glass, Silk, and Wool are Non-conductors.*

The electrical machine, being in operation so as to emit sparks, or to act upon pith balls, or other light bodies, those electrical effects cease, when the conductor, which is the immediate cause of them, is touched with a

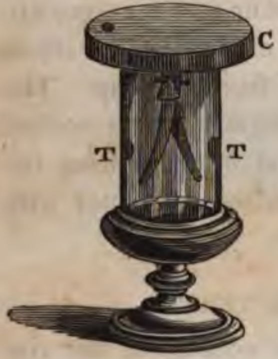
ıomena do not cease, in consequence of the contact
glass rod, or of cylinders of sulphur or resin; nor are
diminished, by an attachment of woollen or silken
ıgs, as in the case of those of flax or hemp. The
s rod, or the woollen or silken strings, being soaked
ater, the electricity is carried off by them from the
luctor. Electricity escapes from the conductor with
through a tube filled with water.

DIFFERENT KINDS OF ELECTRICITY.

may be learned, from the brief account of the rise
progress of electricity, (page 6) that the electrical
ement which may be produced in glass, by friction,
rs from that which may be produced, by the same
ns, in resin, or sulphur: that light masses, as paper,
ith balls, separate from each other, when either ex-
nent has been imparted to both: but if one body re-
es the resinous, the other the vitreous excitement, an
ıction between them will ensue. Both excitements,
ıe proportion, neutralize each other. Also, whenever
er excitement is produced, in one body, the other will
in some other, if both bodies be supported by non-
luctors, so as to prevent the escape of electricity as
as generated. Hence if a person, standing on a

chine is put in motion, the insulated cushion which rubs it, acquires the resinous excitement, while the prime conductor becomes excited vitreously. If a globe of sulphur, or resin were substituted, the cushion would receive the vitreous excitement, while the conductor would be excited resinously.

10. *Description of Bennet's Gold Leaf Electrometer.*



A glass cylinder, supported by a metallic pedestal, is surmounted by a metallic canopy; from the centre of which, two tapering strips of gold leaf are suspended. Strips of tin foil, T T, are pasted on the glass, so as to terminate at the upper ends a little above the level of the lower ends of the gold leaves, and so as to be in contact below, with the pedestal. This should be uninsulated. The gold leaves are more energetically attracted in consequence of the proximity of the tin foil.

11. *Experimental Illustrations.*

The leaves of the electrometer diverge on the approach either of excited sulphur or glass; but when both are approximated to it at once, the leaves will display no divergency.

Electrical machine shown, each conductor being furnished with a quadrant electrometer. As the cylinder is turned, the pith ball of each electrometer rises. As often as a spark is taken from either conductor, the pith ball of the electrometer on it falls; and when a metallic wire is made to touch both conductors simultaneously, neither of the pith balls indicates any excitement.

Of Electric Poles and Electric Circuits.

There is a resemblance which will hereafter be recurred to, between the reciprocal action of magnets and that of electrics, of which the extremities are in opposite states. Under such circumstances, the poles similarly electrified, or similarly magnetised, appear to repel each other; while those in dissimilar states appear to exercise a reciprocal attraction.

The extremities of the magnets, from their exercising a reaction with the terrestrial poles analogous to that which they exercise reciprocally, were called poles; that which is attracted by the north pole of the earth being designated as the north pole, the other as the south pole. From the analogy, the extremities of excited electrics, and of galvanic and voltaic instruments having properties resembling those of excited electrics, received the same appellation. Hence electricians speak of the positive and the negative poles, of the electric machine, of the galvanic battery, or of a voltaic series, whether in the form of the trough, or of the pile.

As a general definition, poles may be alleged to be those parts of an electric, galvanic, or voltaic circuit, at which ignition, light, chemical decomposition, or sensation are perceived.

When the conductors of a machine in operation communicate by a wire or rod, or other competent conducting body or bodies, an *electric circuit* is said to be formed. The electric fluid flowing into the cushion from the negative conductor supporting it, is by the electric carried to the positive conductor, whence, by means of the conducting communication, it returns to the negative conductor. Agreeably to the hypothesis of two fluids, there is in such case a double circuit. Two fluids, separated from each other by the friction, move in opposite directions, and meeting and combining in the conductors as soon as separated, the equilibrium is not sensibly altered.

In making or breaking such a circuit, sparks will appear at the time and place, when and where the interruption is such as to allow them to occur. In that case the poles are at the points through which the sparks pass.

The poles of an electric machine and *the conductors* are often mentioned as if they were identical. In fact, the poles are usually at some points in the surfaces of those conductors. They vary, however, at the pleasure of the operator; since they always exist at those parts of the conductors (or of any conducting body or bodies touching one or both) which are nearest to each other, or at which sparks pass.

It should be understood that any conductor, especially any perfect conductor, assumes the same electric state as the pole, with which it may be in connexion; and that a contact between either pole, and one extremity of a rod, or wire, transfers the polar influence to the other end of that rod or wire. The pole is properly, that point at which the excitement is most active, and experience shows this state to exist always, either at the most prominent part of the electrified mass, or that nearest to any prominent part of the other pole.

In operating with an electric machine, of which the rubber is uninsulated, the earth usually forms a part of the circuit, and any conductor, the human body for instance, which, while it has a conducting communication with the earth, happens to be nearest to the positive pole, acts as the negative pole, when the machine is in operation, and there is sufficient proximity. This is indicated by the passage of sparks.

I have dwelt upon this subject more particularly, as the acceptation of the word pole among men of science has latterly, by its practical and theoretical associations, become of the highest importance.

MEANS OF ACCUMULATING ELECTRICITY.

In the case of the insulated conductors of an electrical machine, oppositely excited by the revolution of a glass surface which successively rubs the cushions supported by one of the conductors, and passes under metallic points projecting from the other, it has been shown that it is only necessary to make a communication between them, by a perfect conductor, in order to destroy their respective excitements. It follows that the surcharge in the one, must have been just equivalent to the deficiency in the other; and that of course the whole quantity of electricity in the conductors is the same, whether they be in a state of excitement or of quiescence.

It has also been shown, that the electric fluid does not pass through electrics, or from one part of an electric to another.

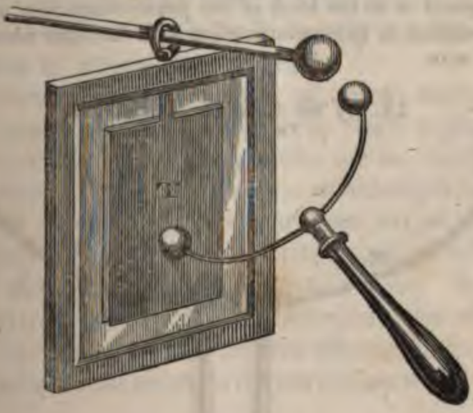
I shall now proceed to demonstrate that, if an electric, sufficiently thin and strong, as a pane of glass for instance, be charged on either side with either kind of electricity, the other side of the pane will acquire proportionably a charge of the opposite nature.

12. *Experimental Illustrations.*

A dry glass pane being held in one hand by its insulating handle, sparks are taken from the excited conductor of an electrical machine, with the knuckle of the other hand. The glass pane, being interposed between the knuckle and the conductor, at first does not appear to intercept the sparks; yet, as they gradually diminish and finally cease, they are obviously intercepted by the pane, sooner or later. The pane being supported by the handle, on touching the surfaces in the part which has been exposed to the sparks with one hand, while the part opposite on the other side of the pane is touched by the other hand, an electrical discharge takes place, a shock is experienced, and the electrical excitement disappears.

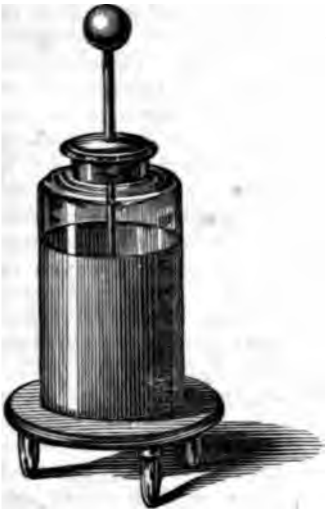
It follows, that the sparks which had apparently passed through the pane, had actually been arrested by the surface nearest to the conductor, and had appeared to reach the hand, because, for every spark received on one side, an equivalent portion of the electric fluid is expelled in the same form from the other side.

13. *Coated Pane.*



A pane of glass is coated on both sides with tin foil, excepting a space of about two inches from the edge all round. The two coatings are made severally to communicate, for a short time, with the two insulated conductors of an electrical machine, while in operation, the coatings being otherwise insulated. The pane being then suspended, and the different coatings severally allowed to communicate through a metallic arc, a charge ensues, more or less powerful, according to the power of the machine, the extent of the coated surface, and the dryness of the air.

14. *Of the Leyden Jar.*



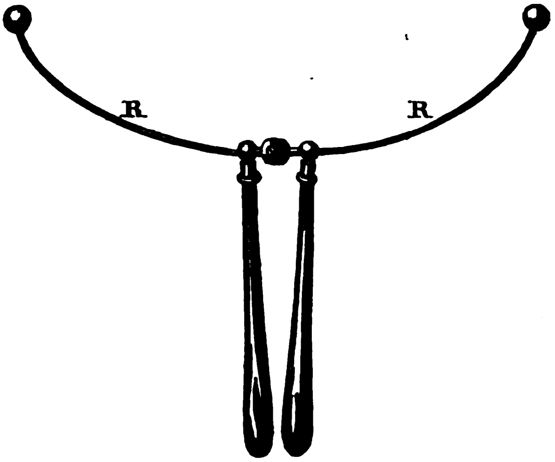
In the Historical Sketch, (page 7) some account has been given of this celebrated invention. The adjoining cut is a representation of it in an approved form. There is no essential difference between a coated phial, and a coated pane. The existence or absence of curvature in the interposed stratum of glass does not sensibly affect the result, either in theory, or in practice, excepting as respects conveniency.

The form of the jar is more favourable to the retention of a charge; as it does not allow such free intercourse between the inner surface and the air.

The coating, it will be observed, is represented as extending both on the inside and on the outside, till within a distance from the brim equal to about one-fourth of the whole height of the jar. The jar is closed by a broad wooden stopple, through the centre of which passes a metallic rod, terminated above by a knob, and below by a spiral of wire, which establishes a sufficient contact with the inner coating.

The most convenient mode of charging such a jar is to grasp it in the hand, and present it to the knob of the prime conductor, while the cushions are uninsulated, or in communication with the outer coating by means of a chain or wire.

15. *Of the Common Discharger.*



This name is given to an instrument, of which the preceding figure is a representation, and which is employed in completing the circuit between the charged surfaces; thus enabling the excess in one to be discharged into the other.

The rods, R, R, are joined by a hinge; so that by means of the glass handles to which they are severally affixed, the terminating knobs may be made to come in contact, or to be remote from each other as in the figure.

A charge is imparted equally well by the co *r communication of either coating with either conduc*

The charging of a coated pane or jar ma ted,
provided either of the surfaces are in commu vith
either conductor, the other surface com with
the other conductor, one or both of the c ng
insulated. In whatever way a charge ma ed, it
will be found that the one surface loses is the
other gains; since a conducting communi vays
sufficient to bring them both back to a state rality.
Hence as the sum of the quantities on both
pane is always the same, charging the pane does
derange the electrical equilibrium of the surround
dium.

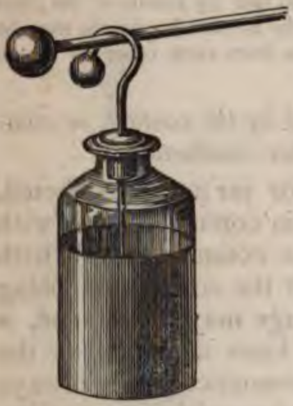
The charge must vary in its strength according t
power of the machine, the dryness of the air, and the thickness of the glass; since the self-repellent power of the electric particles, and their attraction for the negative surface of the glass must be inversely as the squares of the distances at which they operate.

On this account, as a plate of mica may, with less thickness, possess greater strength than a glass pane, it will, in proportion to the respective areas, receive a much higher charge. A certain degree of strength is necessary to enable the glass to resist the intense attraction between the surcharge of electricity on the positive side, and the surface of the glass on the negative side. In obtaining this strength in the glass, we increase the distance between the surfaces, and of course diminish the efficacy of the self-repellent and attractive powers on which the charge depends.

16. *Experimental Illustrations.*

That the charges may be imparted through either coating by either conductor, shown by duly charging and discharging coated panes and jars.

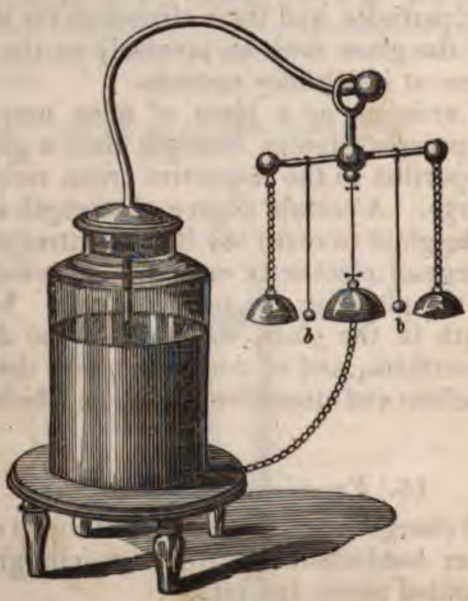
17. *Experimental Proofs that the different Surfaces of a charged Electric are oppositely electrified.*



If from the conductor of an electrical machine in operation, a Leyden jar be suspended by a metallic hook, connected with one of its coatings, it receives no charge until the other coating is approximated by a conducting substance, which communicates directly or indirectly with the other conductor of the machine.

If one or more bodies, as, for instance, little metallic balls, qualified to act as bell clappers, be suspended at a suitable distance between bells severally communicating with the coatings of a charged pane or jar, the balls will play between the bells, demonstrating them to be oppositely electrified by their communication with the different surfaces.

18. *Chime of Bells.*



The little metallic balls, *b*, *b*, and the bell situated between them, being suspended by silk, which is a non-conductor, cannot receive the electrical excitement communicated to the inner coating of the jar. But the two outer bells being suspended by metallic chains from a metallic rod communicating with the inner coating, will partake of the excitement in this coating. Consequently the balls remaining neutral, while the outer bells are excited, are attracted by these, and on coming in contact with them receive a quantity of the electric fluid adequate to bring them to the same degree of excitement. Hence in the next place they separate from these bells, and are attracted by the central bell, which, by means of a chain connecting it with the external surface of the jar, is brought into the same electrical state as this coating, and must of course be in a state opposite to that of the other surface. The balls, by contact with the central bell, lose as much electricity as will bring them to the same state as this bell, and are then separated from this bell; and are attracted by the others, are again separated, and are again attracted, until by repetition they transfer the surcharge on one surface to the other, and thus restore the equilibrium. Gravitation operating upon the balls as upon the pendulum of a clock, evidently conspires to sustain their vibrations.

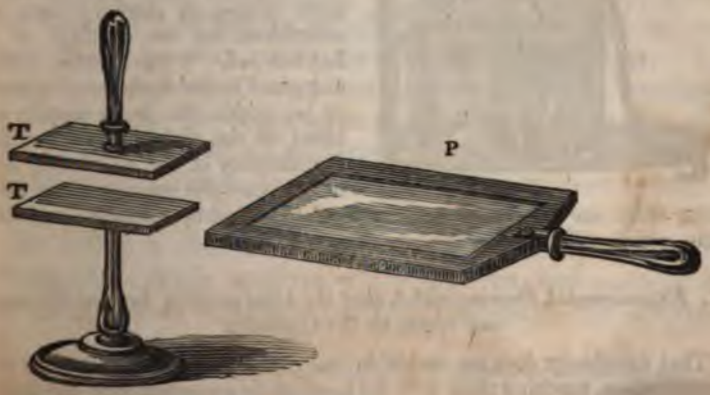
The length of time that the bells may be kept ringing by the vibration of the balls, when the air is dry, may excite surprise at first; but it should be recollected that the balls can only carry off at each stroke a portion of the electric fluid, which is to the whole quantity in the coating, as the superficies of the ball is to the surface of the coating; or less, probably, than as one to ten thousand.

Metallic coatings, employed as in the preceding experiments, are of use in conveying the charge, but do not contain it.

The effect of the tin foil is simply to cause the speedy and equal distribution of the electricity over the surface of the glass, which, being an electric, cannot by itself convey the excitement from one part of its surface to another. Hence a pane without coatings can only be partially charged or discharged at one contact.

19. *Pane with Moveable Coatings.*

T T represents metallic sheets, which are used as coatings to a pane, also represented in the figure. One of the sheets is insulated by being supported upon a stand with a glass leg, the other by being held by a glass handle.

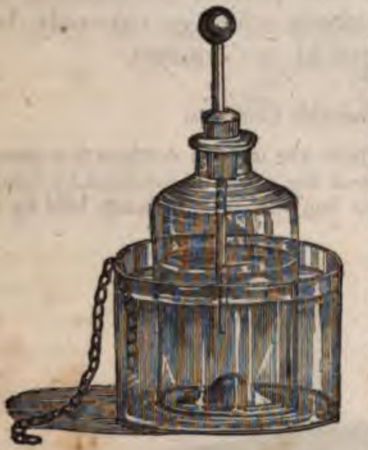


Experimental Illustration.

A glass pane, P, held by means of an insulating handle of the same materials, is made to touch the knob of an excited conductor of the electrical machine on one side; while another metallic knob, communicating with the other conductor of the machine, is made to touch the pane on the other side, in the part opposite to the first mentioned knob. By varying the situation of the knobs, the pane is charged wherever its surfaces have been sufficiently in the vicinity of the knobs. While thus prepared, it is supported by its handle, and one hand of the operator approximated to one side, while the other hand approximates the other. It can only be gradually discharged, as it was charged; the knuckles being made to assume, successively, the various positions relatively to the pane previously occupied by the knobs. But the pane being again charged by the knobs, with the aid of the coatings, T, T, properly applied, the surfaces are thoroughly and instantaneously discharged by contact of the hands or other competent conductor with those coatings. The coatings being applied to the pane whilst charging, and then removed, the discharge can only be effected gradually.

Any other conducting substance which will accommodate itself to the surface of the glass, may be substituted for tin foil. But metals are preferable, as they are pre-eminently the best conductors.

20. *Glass Vessel so situated as that Water is made to perform the same office as Metallic Coatings in the Leyden Phial, illustrating the original Experiment of Cuneus and Mushenbroeck.*

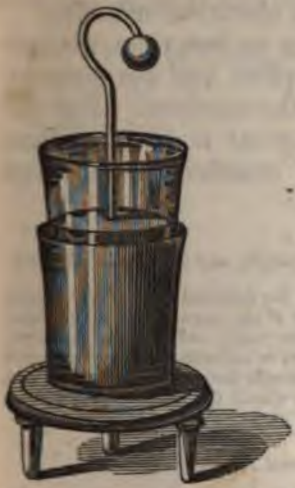


A glass vessel, containing a quantity of water, of which the surface should be about two inches below the brim, and moistened to the same height on the outside, may, as in the celebrated experiment of Cuneus and Mushenbroeck, be charged and discharged by the same means as the pane or phial coated with tin foil, though less advantageously.

Gold, silver, or copper leaf, metallic filings, or mercury may be substituted for the coatings of a Leyden jar. When metallic filings are glued to the surfaces of a pane or jar within the space usually allotted to the tin foil coatings, the discontinuity of the conducting surfaces causes the passage of the electricity from one portion to another to be indicated by splendid corruscations, which will hereafter be fully illustrated.

21. *Experimental Demonstration that the Charge of a Leyden Jar does not reside in the Coatings.*

That the charge does not reside in the coatings, may be proved by removing them, touching them with the hand while separated from the glass, and afterwards replacing them, and simultaneously touching them. A shock will be received in the same way as if they had not been removed.



Instead of tin foil coatings, a metallic case is made just large enough to receive a tumbler with ease, and reaching about two-thirds of its height. A hollow cylinder of the same material is made so as to fill the cavity of the tumbler to the same height as the case reaches on the outside, and yet so loose as to be removed without difficulty. The tumbler being charged in the usual way, the cylinder may in the first place be lifted out of the tumbler by means of a glass rod, and the tumbler in the next place grasped at the brim and lifted out of the case without destroying the charge. This is rendered evident by reinstating the tumbler in its case and the cylinder in the tumbler; and by means of the discharger making a conducting communication between the case and the ball of the wire communicating with the cylinder. An electrical spark will then pass with the usual noise. Or if the circuit be established by touching the knob with one hand and the case with the other, a shock will be experienced.

Of Electrical Batteries.

A series of coated jars being placed side by side in a box, and all the inner coatings being made to communicate with each other, and with a ball of metal, by means of metallic rods; and all the outer coatings being made to communicate with each other, and with another metallic ball, by strips of tin foil, the jars thus associated are called an electrical battery.

Charging and discharging an electrical battery, however extensive, is just as simple, and is performed in precisely the same way, as in the case of a single jar. To charge a single jar, or a battery, the different coatings must be made to communicate, severally, with the different conductors of an electrical machine, either directly, or indirectly through the floor of the apartment or other conducting medium.*

To effect a discharge, either one or several conductors must be made to form a circuit from one coating to the other, either unbroken, or if interrupted, the interval, or the sum of the intervals must not exceed a certain distance, called the striking distance, and which varies with the extent and intensity of the electrical machine.

---

* See Appendix for remarks on the error of supposing that a communication with the earth is necessary, &c. &c.

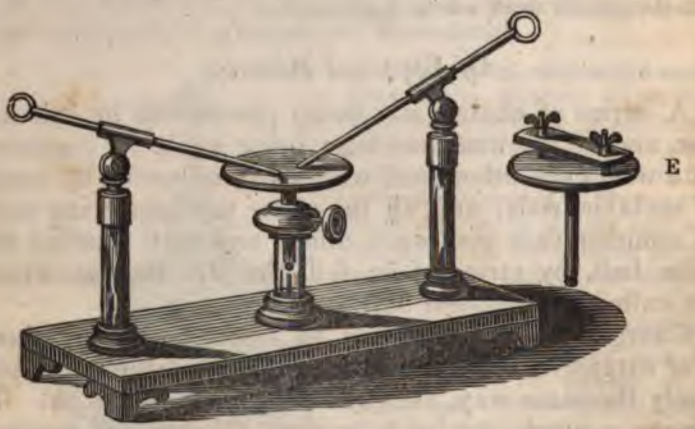
Charging a battery will take more or less time, according to the number of jars to be supplied, and the quantity of the electric fluid generated by the machine. But the discharge appears as quick from a great number as from one, notwithstanding the numerous ramifications through which the electricity has to pass.

22. *Electrical Battery of* 32 *Jars, each* 13 *inches in height, and* 5 *inches in diameter.*

My electrical battery is situated permanently on the external edge of the canopy over the hearth of my lecture room, in the vicinity of my large electrical machine. With the positive conductor of this, it is of course easily made to communicate by a metallic rod. From the outer coatings a wire is extended to one of the iron columns of my lecture room, along which it afterwards descends to my table, and, when the battery is in use, to a sheet of metal on which the battery discharger is placed.

23. *Description of Henley's Universal Discharger.*

This instrument has been employed to facilitate the exposure of bodies to a discharge from a Leyden jar or battery.

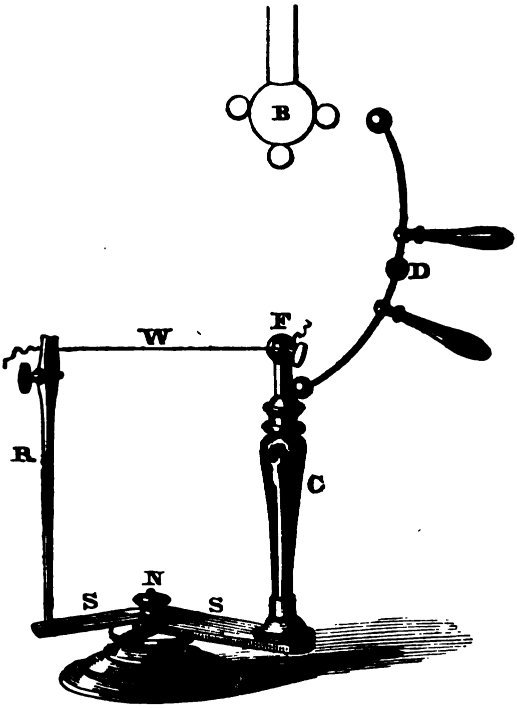


It may be understood from inspection. Two rods are supported upon glass pillars, to which they are secured by universal joints, having not only liberty to move on a pivot in almost any direction, but also to be slid through a spring socket, so as to lengthen or shorten the portion of the rod between the socket and the point. The ends of the wires are pointed, but the points are fitted to brass balls which may be screwed on or off.

Between the columns is a little stand, which may be altered in height by means of a set screw. Upon this stand, an object to be made the medium of a discharge may be placed, the ends of the wires being in due contact with it. To one of the eyes at the other end of the rods, a wire or chains, communicating with a coating of the battery, may be affixed. By means of the common discharger (15) a communication being then made between the other rod and the other coating of the battery, the circuit is completed, and the whole charge of the battery passes through the body upon the stand.

In some cases where pressure is required, the stand represented at E is employed. Thus some gold leaf, being compressed between two very small panes of glass, kept together by the screws with which this last mentioned stand is furnished, may be deflagrated, and incorporated with the glass.

24. *Battery Discharger for deflagrating Wires.*

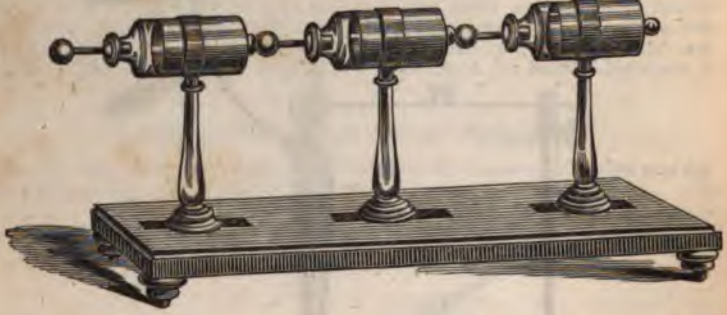


This apparatus is employed by me in lieu of Henley's universal discharger above described, being better adapted to my apparatus and mode of operating. Two brass plates are secured to the pedestal by a screw bolt, N, which passes through a hole made in each, near one extremity; the plates are thus allowed a circular motion about the bolt so as to be set in one straight line, or at any angle with each other. On one of the plates near the extremity not secured by the bolt, a brass socket is soldered, into which a glass column is cemented, surmounted by a forceps. At the corresponding end of the other plate there is a brass rod, R, perpendicular to the plate and parallel to the glass column. This rod is also furnished with a forceps. Between this forceps and that at F, supported and insulated by the glass column, C, a wire is stretched, which may be of various lengths, according to the angle which the plates, S, S, make with each other. The pedestal should be metallic, or have a metallic plate at bottom, in communication with the external coating of the battery. This being accomplished, it is only necessary to charge the battery, without subsequently breaking the communication between the inner coatings of the jars and the prime conductor by which the charge is conveyed. In that case, touching the conductor is equivalent to a contact with the inner coatings of the jars, so far as electrical results are concerned. Hence, by causing one of the knobs of the discharger, D, with glass handles, to be in contact with the insulated forceps, F, and then approximating the other knob to the prime conductor, B, the charge of the battery will pass through the wire, W; as it cannot descend by the glass column, nor reach the operator through the glass handles.

Of Electrical Excitement by Induction.

The simplest case of this kind is that of the Leyden phial, or coated pane, already illustrated, where one surface being in contact with an excited conductor, a tendency is *induced* in the electricity on the other side of the electric to leave it. This probably arises from that self-repellent power between the particles of the electrical fluid with which Franklin supposed them to be endowed.

25. *Apparatus for the Illustration of Electrical Induction.*

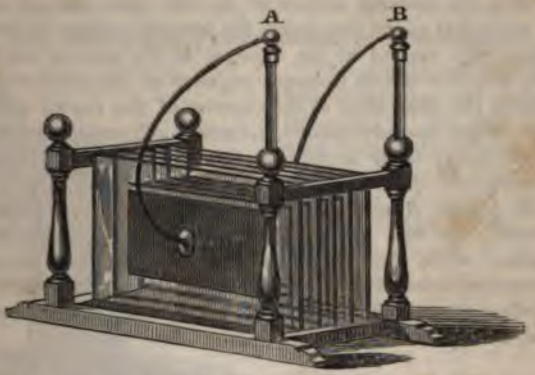


If the outer and inner coatings of two or three insulated jars be made to communicate, and the coatings of each extremity of the series be brought into communication with the conductors of a machine in operation, as usual when one jar is to be charged, it will be found that a charge is received by all; and in discharging them a spark may be perceived to pass between each jar, if a small interval be left. The effect of the discharge is less than that which would be produced by means of one jar. In this case the surfaces are said to be charged by *induction.*

The number of jars which can be thus affected is greater or less, according to the intensity of the electricity evolved by the machine, and the aggregate thickness of glass interposed.

26. *A new Apparatus for the Illustration of Electrical Induction.*

As the prevailing theories of electricity cannot be understood without a correct idea of electrical induction, I have constructed, for the purpose of rendering it more intelligible, the apparatus described in the following article. The surfaces oppositely charged, being in the case of panes exactly alike, renders their commutable relation more easy to understand; and the process, as it proceeds in them, having a greater resemblance to that ascribed to voltaic series, may hereafter be more advantageously cited as a mean of illustration.



A series of five panes coated on both sides with tin foil, excepting about two inches from the edges, are situated in a frame at the distance of about two inches apart. A metallic communication is established between the inner coating of the first pane in the row, and that of the second pane immediately opposite, by means of a spiral spring of wire, which, by its pressure, keeps its place, and produces a close contact with the tin foil. A similar spring is interposed between each pair of coatings. Also the external coating of the first, and that of the last pane in the series, communicate severally by wires with metallic knobs, A, B, supported upon and of course insulated by glass pillars. That is, the first pane communicates with the knob at A, the last with the knob at B.

This apparatus, like a Leyden jar, may be charged in either of three modes. That in which the positive pole alone is insulated from the earth; that in which only the negative pole is insulated; and that in which both poles are insulated.

When the operation is performed with the positive pole insulated, the negative pole communicating with the earth, the surcharge induced in the coated surface of the first pane, expels from the inner coated surface of that pane a portion of electricity, which is of course driven through the spiral into the nearest coated surface of the pane next in order. The surcharge induced thus in the nearer surface of the second pane, causes the other surface of this pane to give up electricity to the nearer surface of the third pane; so that, by a repetition of the process, every pane will be charged, if the electricity be sufficiently intense.

If, under these circumstances, one of the knobs of the insulated discharger be made to touch one of the insulated balls, while an approximation of the other knob to the other ball is effected; a spark will pass, arising from a discharge from the surface of the first pane to that of the last, and at the same instant the equilibrium in all the surfaces will be restored.

During the entrance of the charge, the apparatus only receives an access of the fluid on the external coated surface of the first pane, and loses a portion from that of the last pane. In the other surfaces the quantity is not altered; since whatever one loses the other gains, and the quantities in the surfaces of each pane are equalized with the restoration of the equilibrium of the two external coated surfaces.

When the operation is performed with the negative pole in a state of insulation, it will be the converse of that above described. Electricity being abstracted from the external surface of the fifth pane, instead of being accumulated upon that of the first pane, the internal surface of the fifth pane becomes positively excited at the expense of the nearest surface of the fourth pane, which of course becomes negative on the surface thus robbed, and positive on the other side, at the expense of the coated surface of the third pane. Thus by a successive inductive influence, transmitted from pane to pane, every other surface is negatively charged, causing those which alternate with them to be charged in the opposite way.

When the knobs, A and B, are acted upon by a machine with both poles insulated, the two processes above described co-operate simultaneously: since, while electricity is abstracted from the external surface in direct communication with B, on the right, it is accumulated upon the external surface communicating with A, on the left; so that, by the inductive process, each pane becomes charged.

MEANS OF DETECTING AND MEASURING ELECTRICITY.

It has been seen that the property which light bodies have of separating from, or approaching to each other when electrified, has been of use in showing the nature and extent of electrical excitement.

A ball of pith, supported by a radius, suspended from a pivot, so as to be capable of describing an arc of ninety degrees, over a corresponding curved scale, constitutes Henley's quadrant electrometer, employed in the experimental illustrations (11).

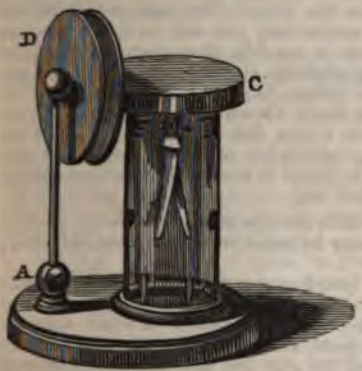
Bennet's electrometer has been described, in which metallic leaves are suspended, within a glass cylinder, to a metallic cap; slips of tin foil being pasted on the glass, opposite and parallel to the gold leaves.

This last mentioned instrument is sometimes more properly called an electroscope; as it is better calculated to discover electricity than to measure it.

The efficacy of the gold leaf electroscope is much increased by the addition of two metallic disks, one soldered to the cap, the other attached to the foot by a hinge; so as that it may be placed parallel, and as near to the first mentioned disk as it can be without touching. In this case, the capacity for electricity of the disk attached to the cap is found to be increased by *induction;* so that it will receive a surcharge. When the disks are separated, the excess of electricity received while they were near each other is indicated by the divergence of the leaves.

The instrument thus constituted is called the condensing electrometer, of which an engraving and description is annexed.

27. *Description of the Condensing Electrometer.*



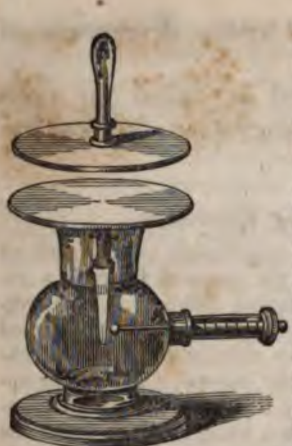
The condensing electrometer, of which the annexed figure is a representation, differs from the ordinary instrument, in being furnished with two metallic disks, one attached to the canopy, C, the other upheld by a wire. The wire terminates in a hinge at A, by which the disk which it supports may be made to approach, or retire from the other disk. The metallic hinge communicates by a strip of tin foil, with other strips of the same material, which are pasted on the glass, as already described in the case of the gold leaf electrometer (10).

In order to put this instrument into operation, the disks must be quite parallel, and as near each other as possible without contact; then, on touching the cap with an electrified mass, containing a charge of electricity otherwise too low to affect the leaves, and afterwards removing the disk D to the distance of two or three inches, the leaves diverge. A divergence of the leaves of the condensing electrometer may be produced by supporting a zinc disk of about six inches in diameter, in the hand or otherwise, so as to have a communication, directly or indirectly, with the pedestal of the electrometer, and placing on it, from ten to twenty times, a disk of copper of the same size, held by a glass handle, and at each removal bringing the copper disk in contact with the cap of the electrometer. By these means a charge is imparted to the cap, which, when the outer disk is removed, is evinced by the divergency of the leaves. For our knowledge of the last mentioned method of producing electricity, by the contact of heterogeneous metals, we are indebted, I believe, to the celebrated Volta.

I have constructed an electroscope with a single leaf, to which a brass ball may be approximated by a micrometer screw. This is more sensitive than any electrometer which I have seen on the usual plan. When furnished with a cap of zinc, if a plate of copper be placed on the cap, and then lifted, the leaf will strike the ball. This instrument acts both as an electroscope and as an electrometer, as it detects and measures the minutest degree of excitement.

28. *Description of the Single Leaf Electrometer, by which the Electricity, excited by the touch of heterogeneous Metals, is rendered obvious after a single contact.*

A single gold leaf is suspended from a disk of zinc six inches in diameter, which constitutes the cap of the instrument. Opposite to this single leaf a ball is supported, which may be made to approach the leaf, or recede from it, by means of a



screw. Of the same size as the disk which forms the cap there is a copper disk with a glass handle, accompanying the instrument.*

The electricity produced by the contact of copper and zinc is rendered sensible in the following manner. Place the disk of copper on the disk of zinc, which forms the cap of the electrometer. Take the micrometer screw in one hand, touch the copper disk with the other, and then lift this disk from the zinc. Usually, as soon as the separation is effected, the gold leaf will strike the ball, if the one be not more than the twentieth of an inch apart from the other. Ten contacts of the same disks of copper and zinc will be found necessary to produce a sensible divergency in the leaves of the condensing electrometer. That the phenomenon arises from the dissimilarity of the metals is easily shown by repeating the experiment with a zinc disk in lieu of a disk of copper. The separation of the homogeneous disks will not be found to produce any contact between the leaf and ball.

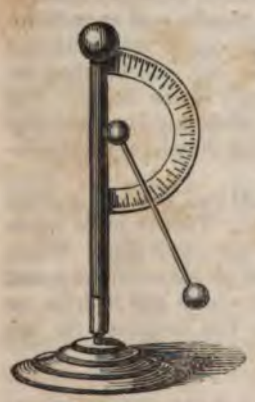
I believe this to be the only mode in which the electrical excitement, produced by the contact of heterogeneous metals, can be made evident without the aid of a condenser.

It is probable that the sensibility of this instrument is dependent on that property of electricity which causes any surcharge of it, which may be created in a conducting surface, to seek an exit at the most projecting termination, or point, connected with the surface. This disposition is no doubt rendered greater by the proximity of the ball, which increases the capacity of the gold leaf to receive the surcharge, in the same manner as the uninsulated disk of a condenser, 27, influences the electrical capacity of the insulated disk in its neighbourhood.

It must not be expected that the phenomenon above described can be produced in weather unfavourable to electricity. Under favourable circumstances, I have produced it by means of a smaller electrometer, of which the disks are only two and a half inches in diameter.†

The construction, as respects the leaf and ball, regulated by the micrometer screw, remaining the same, the cap of a condensing electrometer and its disks may be substituted for the zinc disk.

29. *Description of Henley's Quadrant Electrometer.*



Henley's electrometer consists of a little wooden column, supporting a semicircle of ivory, or of wood covered with white paper, graduated near the periphery into 180 degrees. At the centre of the semicircle there is a pin, from which a moveable radius terminated by a pith ball is suspended. This radius is sufficiently long to allow the ball to reach to the base of the column, against which, when left to itself, it rests. But when the ball and column are electrified, the ball moves off from the column, together with the radius to which it is affixed. But the radius being secured to the pivot at its upper end, the ball must describe a greater or less portion of a circle, which is at the same time indicated and measured by the graduation.

---

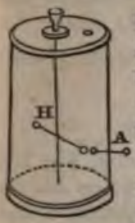
* For the experiment with this electrometer, a metallic handle would answer. Its being of glass, enabled me to compare the indication, thus obtained by my instrument, with that obtained by a condenser.

† I think I have seen an effect from a disk only an inch in diameter, or from a zinc disk having a handle with a copper socket.

30. *Description of Coulomb's Electrometer.*

The electrometer of Coulomb is suitable rather for the investigation than for the illustration of electrical phenomena. Yet as it may be proper to convey an idea of the principle of this instrument, I shall quote from the Treatise on Heat and Electricity of the distinguished Dr. Thomson of Glasgow, a description, accompanied by an engraving of the electrometer in question in the most simple form. Alluding to the gold leaf electrometer, (10) or that in which straws are used in place of gold leaves, Dr. Thomson observes:—

> "In these and many other common electrometers which I think it needless to describe, the instrument cannot be considered as a true measurer of the quantity of electricity; because as the two straws or the two slips of gold leaf separate farther and farther from each other, it is evident that gravitation will act more and more powerfully to bring them back again to their naturally vertical position. Hence the repulsive force of the straws, or leaf, is not proportional to the distance to which they separate from each other. These instruments cannot of course be employed to measure the energy of electricity.
>
> "But the electrometer of Coulomb is free from this defect. It is represented in the margin. It consists of a glass vessel having a lid also of glass, in the centre of which a small hole is drilled. Through this hole passes an untwisted raw silk thread four inches long, and fixed at the top to a micrometer, by means of which it may be turned round any number of degrees at pleasure. To the silk thread is attached a very fine gum lac thread, H, having at each extremity a small knob. This lac needle with its knobs weighs only one-fourth of a grain. A small hole is drilled in the side of the vessel, at A, through which passes a fine wire terminated at both extremities by a knob. When an excited body is placed in contact with the knob at A, the knob at the other extremity will acquire the same electricity as the excited body. This electricity it will communicate to the knob of the lac needle suspended by the silk thread which was previously almost in contact, and the two knobs will repel each other. The moveable knob attached by the silk thread will separate from the other, and the quantity of electricity will be proportional to the distance to which it is driven off.
>
> "Coulomb's electrical balance is an instrument intended to measure the quantity of electricity in bodies, and indispensable in accurate experiments."



It should be understood that in this instrument, the knob of the suspended needle may be made to resist sufficiently its removal from that supported by the wire, by twisting the silken fibre. Coulomb contrived a more perfect and complicated electrometer, upon the same principle as the one which I have described, but furnished with graduated circles for measuring the distance between the balls, and the extent of the torsion given to the suspending filament.*

By means of this apparatus, Coulomb confirmed an observation previously made by the Earl of Stanhope, that the density of electricity in the electrical atmosphere, surrounding an excited body, diminishes inversely as the square of the distance from the charged body. Coulomb inferred, from the law thus assumed to exist, and from ingenious and accurate experiments tending to corroborate his inference, that the electricity accumulated about a conducting body is entirely superficial, none of it existing in the interior of the body. He also, as Dr. Thomson conceives, "proved by very simple but convincing experiments, that electricity deposites itself upon bodies according to their surfaces; that it has no more attraction for one body than for another: also, that if two bodies, having the same surface, be placed in contact, whatever their nature may be, any electrical surcharge in either will be divided equally between them." Allowance is to be made for the obstruction arising from the diversity of conducting power, which, however, only delays the equalization, but does not prevent it from taking place.

---

* The description of this last mentioned instrument, with engravings, occupies three pages in the Treatise of Dr. Thomson, alluded to above, which is more space than I deem it expedient to devote to the same purpose.

EFFECTS OF ELECTRICITY.

The separation or approximation of electrified bodies, the extrication of light and heat, and the shock given to the animal frame, having been all, more or less, subjects of discussion, or adduced as the means of experimental illustration, it may now be proper to display a greater variety of electrical phenomena, and such as being more complicated require undivided attention on the part of those who would comprehend them.

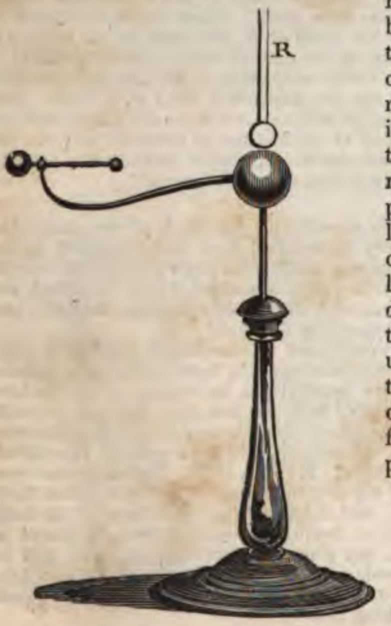
Of Electrical Attraction.—Of Electrical Light.—Of Electrical Ignition.—Of the Electrical Shock.—Of Mitigating the Effects of Electricity.

Of Electrical Attraction.

Under this head are placed both the separation and approximation of light bodies, when electrified; since the former, though commonly ascribed to repulsion, is really, as I conceive, the effect of attraction.

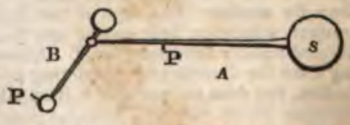
31. *Revolution of a Sun, Planet, and Satellite.*

Fig. 1.



A hollow brass globe, Fig. 1, is rendered much heavier on one side by running into it a quantity of molten lead, sufficient to occupy about one-third of the cavity. By these means, when supported on a pivot, it preserves a proper position, although on the other side not furnished with lead, it is made to support an arm and two balls; one larger, representing a planet, the other smaller, representing its satellite. These are carried upon the different ends of a wire passing through their axis, and balanced upon the point of the arm, so that the balls may counterpoise each other. From the larger arm, and from the smaller ball, points P, P, project, as represented in Fig. 2.

Fig. 2.



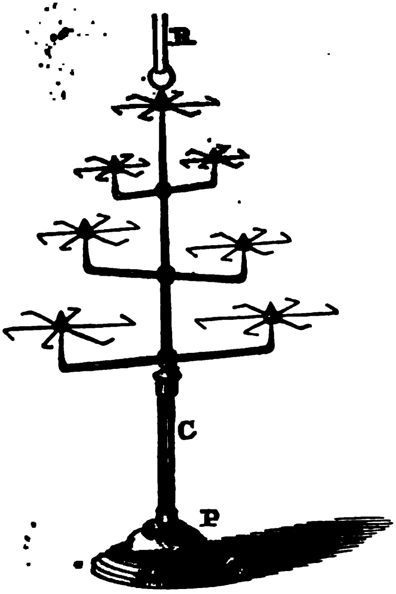
When the sliding rod of the conductor R, is brought sufficiently near to the central globe of this apparatus, the machine being in operation, there ensues a complicated revolution. The planet and its satellite, attached to the arm B, are balanced upon a pivot, formed of the recurved and pointed termination of the larger arm A; meanwhile the pivot revolving as the sun S turns upon its axis, carries the planet and satellite in their orbit, while they revolve about the pivot as their common centre of gravity.

According to the Franklinian theory, the above described rotatory motions result from the attraction of the surrounding medium, operating successively at every part of the orbit, to separate the electrified air from the metallic points by which it is electrified.

It must be admitted that as these rotatory motions may be produced whether the excitement be negative or positive, the rationale is more difficult of conception upon the theory of one fluid than upon that of two. It is necessary, agreeably to the Franklinian doctrine, to ascribe all cases in which electrified masses separate from each other, to attraction between them and the matter of the adjoining medium. This process becomes extremely difficult to follow in the "mind's eye," when the masses thus separated are undergoing a rapid change of position.

The explanation, supposing two fluids to exist, is simply that bodies similarly excited repel each other; and consequently that repulsion arises between the points and the air which they electrify, whether the excitement be vitreous or resinous.

32. *Electrical Tree.*



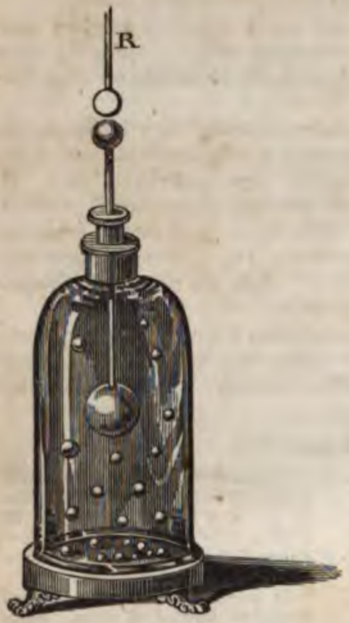
I believe that an apparatus resembling that of which this figure is an engraving, is named in Pixii's catalogue, "Arbre Electrique," a name which I have used for want of a better.

It consists of several sets of branches formed of wire. Each set is associated by a common hollow brass cone, into the apex of which a recurved wire, forming a principal branch of the electrical tree, is so introduced as to form a support and a pivot, upon which the cone and its branches may rotate. Each rotatory branch is recurved, and terminates in a point; the points in each set projecting in the same direction, so as to cooperate in producing a circular motion.

The branches are put into operation by communicating with the machine, as usual, by the rod R. The excitement thus received cannot pass off by the trunk C, which is of glass, cemented into an upright brass rod above, and the pedestal P, below. It can hardly be necessary to add, that the rationale of the rapid rotation of each set of the branches is analogous to that of the preceding experiment. In consequence of their being similarly surcharged with electricity, or similarly deficient, the adjoining neutral medium attracts the air and the branches apart with energy, and thus causes them to recede from each other as soon as they come into proximity.

To render the Franklinian rationale more intelligible, as applied to this experiment, and that of the miniature sun, earth, and moon, it may be observed, that the excitement of the machine being communicated by the sliding rod R, to the central ball, and of course to all of the metallic wires therewith associated, it is diffused through the points to the air in their vicinity. Consequently the points P, P, (fig 2, preceding page,) and the air electrified by them, being similarly surcharged, or similarly deficient, must be attracted by the adjoining neutral medium; and not attracting each other, they are made to separate rapidly, or to move in opposite directions. This process being reiterated with inconceivable speed, the revolutions proceed with proportional velocity.

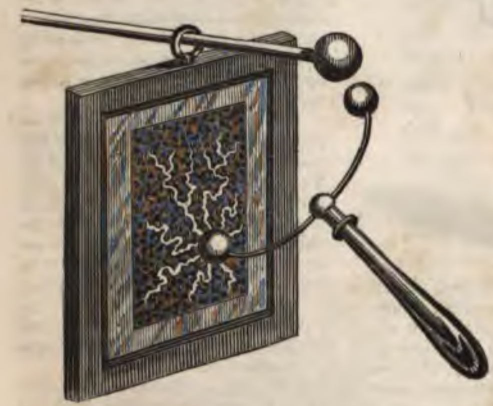
33. *Electrical Hail.*



This experiment, which is in Pixii's Catalogue described as "Grèle Electrique," (electrical hail) affords another illustration of the movements which may be produced in light bodies by electrical attraction. A metallic rod supports one ball within the bell glass, another without, so as to be in contact with the knob of another rod R, proceeding from the conductor of the large electrical machine in operation. The brass ball being by these means intensely electrified, attracts some of the pith balls which lie upon the metallic dish in which the bell is situated, and which should communicate with the cushions of the machine. As soon as the pith balls come in contact with the electrified ball, becoming similarly excited, agreeably to the general law, they recede from each other, and are attracted by the oppositely electrified dish. Reaching the dish they attain the same electrical state as at first, and of course are liable to be attracted again. Meanwhile other balls are undergoing the same routine, producing that contrariety of movements which characterizes the fall of hail.

Of Electrical Light.

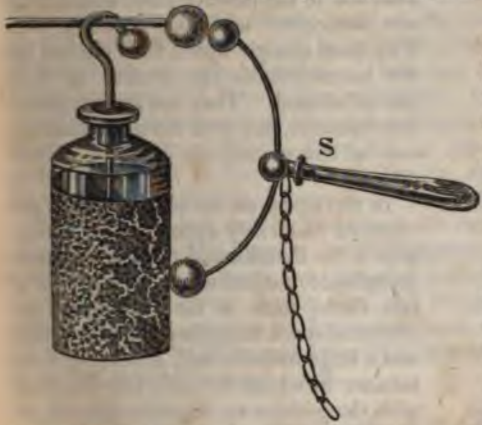
34. *Experimental Illustration of the egress and access of the Electric Fluid during the charging and discharging of coated surfaces, as rendered evident by means of a discontinuous coating of Metallic Filings.*



The charging and discharging of a coated pane has already been illustrated and explained. The process is however rendered much more interesting, when, instead of a continuous coating of foil, a covering of metallic filings is applied, so as to leave a multitude of minute intervals between the particles of the metal. It is only necessary to have the discontinuity of covering on one of the surfaces; the other may be coated with tin foil as usual.

The tin foil coating should, by means of a strip of the same substance, communicate with the ring attached to the wooden frame in which the pane is secured. Let the pane, thus prepared, be suspended by the ring, as represented in the engraving, from a rod affixed to the conductor of a powerful electrical machine in operation. As represented in the figure, let a discharger be so held, in contact with the surface coated with filings, as to carry off electricity from it, allowing the other surface of the pane to be proportionably surcharged. In the next place, let the discharger be so situated, as to complete the circuit between the surfaces, allowing the surcharge in the one to rush to the other. By these means the efflux and afflux of the electric matter will be indicated by coruscations of electric light with an indescribable splendour, which will appear so long as the surface coated with tin foil remains in communication with a machine sufficiently active, and the situations of the discharger are alternated as above described.

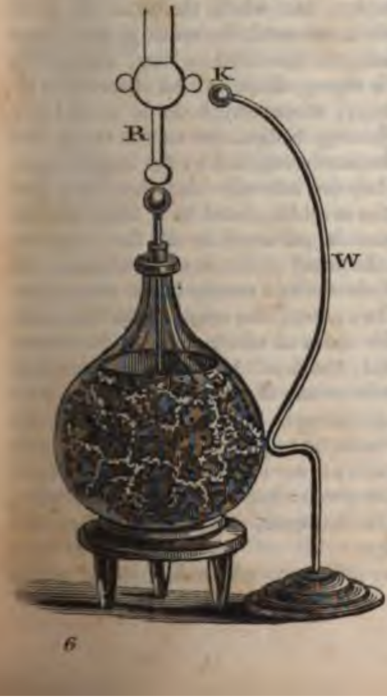
35. *Experimental Illustration.*



Analogous results may be obtained by means of a jar represented by the adjoining figure, which has a hook wherewith to suspend it; or still more advantageously by means of a large carboy, silvered with an appropriate amalgam within, and on the outside furnished with a discontinuous coating of filings.

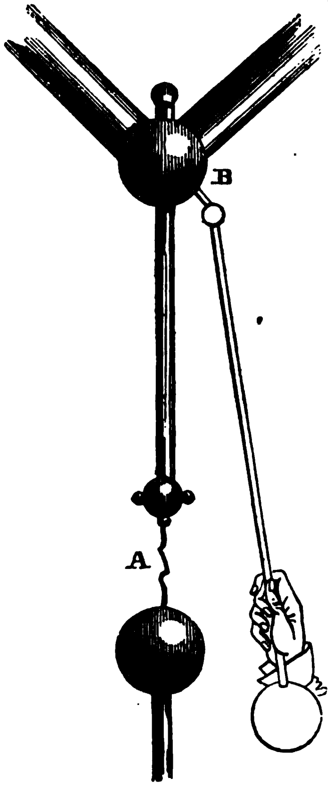
If the discharger employed in this experiment have a glass handle, either the metallic socket, S, into which the handle is cemented, must be touched by one of the fingers, or a wire must be attached to it, making a communication with the negative conductor, directly or indirectly. Otherwise, the external coating being insulated, electricity could not escape from it, and of course the inner surface could not be charged as already demonstrated.

36. *Experimental Illustration.*



The adjoining cut represents a green glass carboy of about five gallons in capacity, coated internally by means of the amalgam usually employed for the purpose; externally by brass filings, as in the cases of the pane and phial above described. It is situated under the projecting ball of the prime conductor, so that the knob at the top of the rod, proceeding through a cork from the internal coating, may be in contact with the sliding rod, R, of that conductor. The wire, W, is supported on a pedestal in contact with the external coating of the carboy, and in communication with the negative conductor of the machine. Hence, when by the operation of the electrical machine, the internal surface of the glass is becoming charged, the escape of the electricity from the external surface is indicated by coruscations of light, and snapping sounds, as in the preceding experiments; and at the instant when the charge acquires sufficient intensity to jump through the interval between the knob attached to the ball, and that supported by the wire, at K, the deficit created in the external surface being restored at once, the coruscations and sparkling are particularly splendid.

37. *Long Zigzag or Erratic Spark, contrasted with the Short Straight Spark.*



The object of this engraving is to represent the different forms and lengths of the electric spark, which take place between a large and a small ball, accordingly as they are made negative or positive. The long and zigzag, or erratic spark A, takes place between a small ball attached to the positive pole, and a large one associated with the negative pole. The short straight spark B, is elicited under circumstances the reverse of those just mentioned. They are represented as simultaneous, but, with the same machine, can of course only be obtained in succession.

In no respect do the phenomena of mechanical electricity appear more favourable to the Franklinian theory, and more inexplicable according to the doctrine of two fluids, than in the diversity of the electrical spark in passing between a small and a large metallic ball, according to the manner in which the balls are associated with the positive or negative poles of the machine. When the small ball is attached to the positive pole, the spark is long, comparatively narrow, and of a zigzag shape, such as lightning is often seen to assume; but when the situation of the balls is reversed, the spark is straight and thick, not one-third as long, and nothing of a zigzag shape can be observed in it.

According to the Franklinian theory, when any body is more highly charged with electricity than the adjoining bodies, the excess of the fluid is attracted by them, while it is inadequately repelled by the inferior quantity of the electric fluid, with which they are imbued. It follows that when a small globe is made positive in the neighbourhood of a large one, the excess of electric matter in the former is attracted by all the negatively excited metal in the latter. When the small globe is made negative, the metal of which it consists attracts all the electric matter in the large globe. Hence there is this difference in the two cases; the small globe being positive, a comparatively small *moveable mass* of electric matter is attracted by a large immoveable mass of metal: the small globe being made negative, a large *moveable mass* of electric matter is attracted by a small immoveable mass of metal. The charge being in both cases the effect of the same machine, the attractive power must be as great in one case as in the other. The forces by which the masses are actuated being therefore equal, it is quite reasonable that the greatest projectile power should be attained, when the small mass is moveable. In that case, it will require less air to be removed in order to effect a passage.

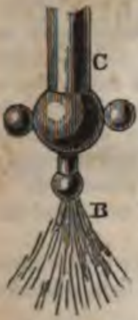
There is an analogy between the difference which I suppose to exist in the case under consideration, and that which may be observed between the penetrating power of a rod which is blunt, and one which is pointed.

It remains to be shown why a large mass of electric matter will be discharged in a spark when there is sufficient proximity; although that electric matter be situated in the large globe, and attracted by the other, under circumstances in which, as above stated, it would not pass without that proximity.

It must be evident that attraction increases as the distance between the bodies which exercise it lessens. Of course the attraction of the small globe must always act more powerfully on those portions of the electric fluid, which occupy the nearest parts of the positively excited globe. But this difference of distance, and consequent diversity of attraction, increases as the globes are approximated. Thus that portion of the electric fluid which sustains this pre-eminent attraction, will be accumulated into a conoid; the acuteness of which, and attraction causing the acuteness, increasing with the proximity, there will at last be sufficient projectile and penetrative power to break through the air, and thus open a passage for the whole of the quantity attracted by the small negatively excited globe.

When, by the process last described, the fluid is made to leap through a comparatively small interval, by the concentrated attraction exercised by a small negative ball upon the expanded surface of electric matter diffused through a large globe; the air does not become sufficiently condensed to resist it before it reaches its destination, and, of course, it cannot assume the erratic form which would arise from repeated changes in its course, as in the instance of the long spark.

38. *Electrical Brush.*



When the machine is in active operation, and the prime conductor insulated, the electricity will be sent off from a small knob attached to it, as at B in the figure, so as by the concomitant light to exhibit the form of a luminous brush, as represented in this figure at B. For the production of this phenomenon, it is necessary that the electric fluid shall be condensed into a small prominent mass, so as, agreeably to the preceding explanation, to have great penetrating power. This it cannot possess, when, with the same intensity in the generating power, a large ball is positively electrified. In that case, the electric column presents a front too broad to procure a passage through the surrounding non-conducting air. A small ball, negatively electrified, can only be productive of a diffuse attraction for the electricity in the atmospheric medium around it; so that it has less ability to create any penetrating power, than when acting upon the electricity in a comparatively large globular conductor, as in the preceding illustration. Hence, when the knob is on the negative pole, it may be productive of a luminous appearance in its immediate vicinity, where the electric matter, converging from the adjoining space, becomes sufficiently intense to be productive of light; but it does not produce the striking appearance of the luminous brush.

As, agreeably to Du Fay's theory, the knob, whether vitreously or resinously electrified, is surcharged with an electric fluid, the projectile power ought to be as great in the one case as in the other; and the long spark and the brush should be producible in either case.

On some Inferences from the Phenomena of the Electric Spark, contained in a recent Work on Heat and Electricity.

In his valuable work on heat and electricity, Dr. Thomson states that if a long spark be taken between two knobs, as when severally attached to the positive and negative conductors of the electrical machine; the portion of the spark near the positive knob exhibits all the characters of positive electricity, while the remaining portion proceeding from the other knob displays all the characters of negative electricity. Although the learned and ingenious author does not state what differences there are between the different portions of the spark, and wherefore, if any exist; he can, without a petitio principii, assume that they are such as to justify his conclusion. He proceeds to allege that there can be no doubt that every spark consists of two electricities; which, issuing severally from their respective knobs, terminate their career by uniting at the non-luminous portion of the spark, which is at a distance from the negative knob of about one-third of the interval. Upon these grounds he infers that the positive electricity occupies two-thirds of the length of the spark, the negative one-third.

I presume, agreeably to the theory which supposes the existence of two fluids, that, when the equilibrium between oppositely excited surfaces is restored by a discharge, whether in the form of a spark or otherwise, there must be two jets or currents passing each other; the one conveying as much of the resinous as the other does of the vitreous electricity. Of course no part of a spark can be more negative than it is positive, nor more positive than it is negative. Upon this ground, a suggestion of the same author that the diminution of light near the middle of the spark results from the combination of the different fluids at this point, appears to me injudicious; since there is as little ground for supposing the union of the fluids to take place there as elsewhere. But admitting that the union does take place as supposed, is this a reason for the observed diminution of light? If, when isolated, either fluid is capable of emitting a brilliant light, should not their co-operation increase the effect? If, after their union, they do not shine, it can only be in consequence of their abandoning, at that moment, all the light with which they were previously associated. It cannot be imagined that the light accompanying one should neutralize that accompanying the other.

In deflagrating, by voltaic electricity, a wire of uniform thickness, equally refrigerated, the most intense evolution of heat and light is always midway.

In truth, the theory which the learned author sanctions, requires two postulates so irreconcilable, that unless one be kept out of view, the other cannot be sustained. It requires that the fluids should exercise an intense reciprocal attraction adequate to produce chemical affinity, and of course, enter into combination when they meet, and yet rush by each other with inconceivable velocity, not only through the air, but also through the restricted channel afforded by a small wire. If the fluids combine at a point intervening between the surfaces from which they proceed, what becomes of the compound which they form? Is it credible that such a compound would afford no indication of its existence? But, again, how are two surfaces, the one previously deprived of a large portion of the negative electricity naturally due to it, the other made as deficient of the positive fluid, to regain their natural state? By a combination midway, the resinous and vitreous surcharges might be disposed of, but whence could the vitreous and resinous deficiencies be supplied?

Dr. Thomson, in common with the great majority of modern chemists, ascribes chemical affinity to the attraction between the two electricities combined with ponderable particles. As the combinations between such particles take place only in definite proportions, would it not be consistent that the fluids which give rise to them should combine agreeably to those laws? But if the electrical compound, formed of the vitreous and resinous electricities, be decomposable by induction, as the theory in question requires, its constituents must be capable of uniting in every proportion.

Agreeably to the late investigations of the celebrated Faraday, equal quantities of the electric fluid are evolved, by analogous chemical changes, from equivalent weights of different ponderable bodies. It may, therefore, be inferred, that in entering into combination, the electric fluid is obedient to those laws of definite proportion which regulate other substances.

39. *Illuminated Globe, Pane, and Tube.*

Fig. 1.

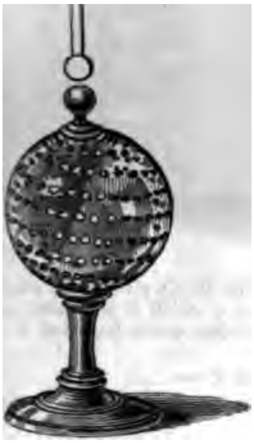
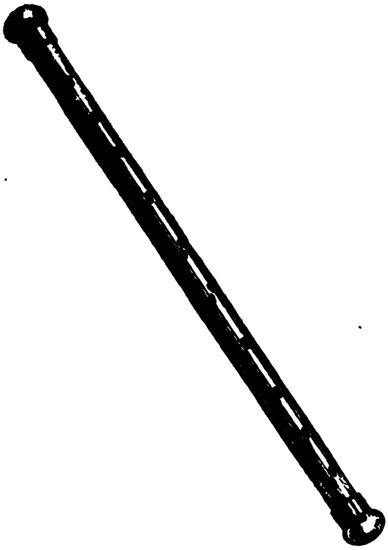


Fig. 2.

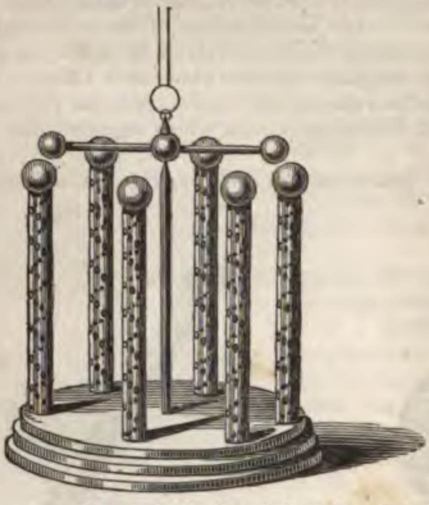


Little disks of tin foil are so pasted in succession on a glass globe, pane, or tube, as to leave only a minute interval between them. In consequence of this arrangement, when situated in the circuit between the poles of an electrical machine, the electric fluid availing itself of the conducting power of the metal, and leaping over each interval, produces as many sparks as there are intervals. At the same time, if these intervals fall within the lines of any drawing, the image representing the drawing will appear at each flash; and when, as in using a large machine, the flashes are incessant, remitting without intermitting, the effect upon the eye is nearly as permanent as if the illuminated spaces were inherently luminous.

In the case of the globe and tube represented by figures 1 and 2, the disks are arranged in spirals, winding about the globe or tube from one apex or end to the other. However intricate the route which ingenuity may, by means of the foil, prescribe, it will be pursued by the fluid with fidelity, when the air and pane are dry. Yet the sum of the intervals must not exceed the whole striking distance of the machine, or in other words, the greatest length of its spark.

This illustration may be varied by means of apparatus, of which engravings and descriptions will be found in the two following articles.

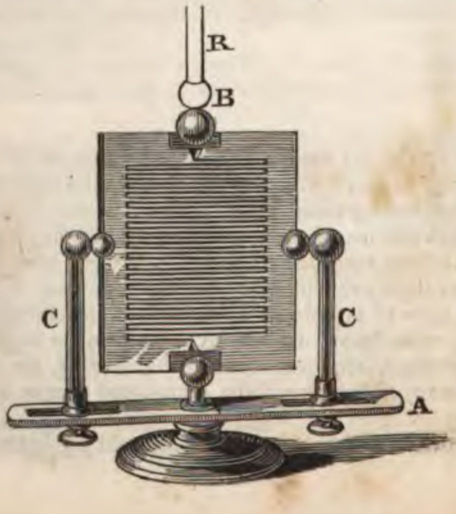
40. *Illuminated Columns.*



A swivel of wire, terminating in knobs, is so balanced upon a pivot, that, when charged, it revolves from the brass knob of the column to which it is nearest, to that of the next, and thus successively conveys to each the sparks imparted to it by the machine.

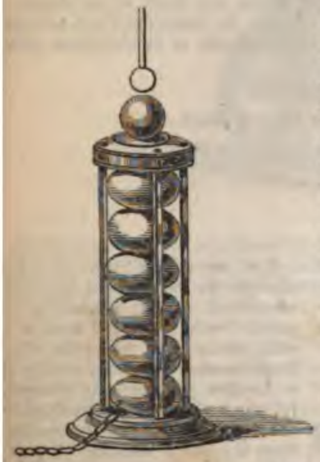
41. *Carreaux Etincelantes.—Sparkling Panes.*

This appellation is given in Pixii's Catalogue to the apparatus described in the following article.



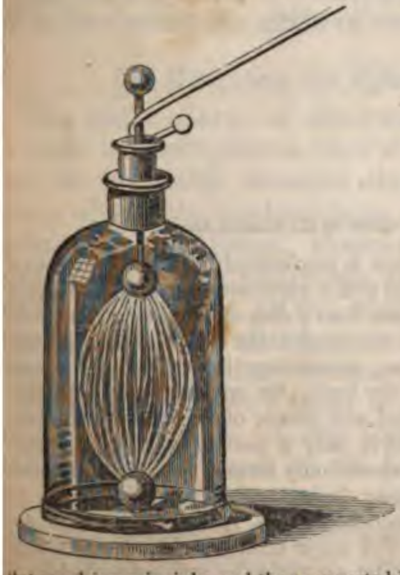
The preceding figure represents a pane, in which the discontinuities in the tin foil tached, as explained, (39) being made to occur along the lines of a drawing, an mage is seen as often as the electric spark passes. The frame, A, having two glass olumns surmounted by metallic clasps for securing the pane, is contrived to acommodate a succession of panes, all of one size exactly, on which different images re delineated, and which may be shown in succession. In operating, the upper ball, B, is situated so as to be in contact with the sliding rod, R, of the prime conductor. At this point, the fluid enters, and coursing horizontally, first towards one side, and then towards the other, it finally escapes at the other ball into the foot of the instrument, which should communicate with the cushions of the machine, directly or indirectly.

42. *Illuminated Eggs.*



Between three glass columns a pile of eggs is supported in mutual contact. They are also in contact at top and at bottom with spiral wires; in the one case communicating with a chain, in the other, with a brass knob which surmounts the cap in which the columns terminate, and by which they are secured. The eggs thus situated may be taken into the circuit between the conductors of the machine, or the coatings of a battery, and thus be illuminated by the passage of the electric fluid. The experiment is seen to the best advantage when a powerful machine is employed, as the effect is in that case durable; scarcely any intermission taking place in the flashes. The contents of the eggs appear to be exposed to the eye, as if divested of their shelly covering.

43. *Electric Light in Vacuo.—Aurora Borealis.*



It appears from the experiments of Volta, that electrical excitement is consequent to the vaporization of water. In fact, to what other cause than the successive formation and condensation of vapour, are we to ascribe the prodigious evolution of electricity which accompanies thundergusts. Those portions of the earth which are within the arctic or antarctic circles, must, in consequence of their frigidity, be incessantly receiving accessions of moisture from the atmosphere, which, as its capacity for moisture varies with the temperature, must, whenever it is carried by circulation to that icy region, part with a portion of the water which it absorbs in warmer latitudes. Indeed, independently of those aërial currents which would favour this result, the law of the diffusion of vapours would cause it incessantly to extend itself from warmer latitudes, where it is supplied with the caloric requisite to its formation, towards those colder regions in which it is deprived of that repulsive principle, and thus converted into snow.

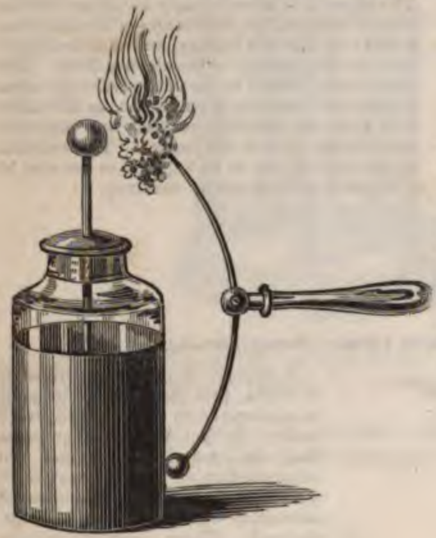
Here then is a great source for electrical excitement. Meanwhile the same frigidity which causes all vapour to condense, coats the whole surface of the earth in the vicinity with dry ice, which is well known to be an electric. How is the electric fluid thus accumulated to escape? It can have but one of two courses. Either it must strike through the dense air near the earth's surface horizontally, or penetrate through the rare medium above, where, as it proceeds, the resistance will lessen. The last mentioned course is obviously preferable; since, at a distance less than half a degree of latitude, it will find a medium as rare as that in the receiver of the finest air pump.

I infer that the coruscations of the aurora borealis are produced by the efforts of electricity accumulated as above described, to seek that equilibrium to which it incessantly tends. I conceive myself fortified in this inference by a striking resemblance between the coruscations of that principle in passing through an exhausted receiver, as represented in the preceding figure, and those of the aurora.

The figure represents only one of the appearances. At times the fluid will pass only on one side, and then successively shift to the opposite or intermediate paths.

Of Electrical Ignition.

44. *Ignition of Cotton by the Electric Spark.*



Let one of the knobs of a discharger be surrounded by a tuft of carded cotton, containing as much finely powdered rosin as it will retain; and while the other knob touches the outer coating of a Leyden jar properly charged, let the cotton be approximated to the knob of the jar proceeding from the inner coating. A spark will pass, and the cotton will be ignited.

45. *Inflammation of Ether by the Electric Spark.*

This object is conveniently effected by means of a wine glass with a perforated stem, through which a wire passes from a dish of metal cemented to the foot. The wire rises about two-thirds of the height of the glass, terminating in a knob. Up to the middle of the knob, the cavity of the wine glass may be filled with plaster of Paris, or other cement, so as to leave only a portion of the knob bare. The ether should only form a thin stratum not entirely covering the apex of the knob.

In consequence of its ready vaporization and admixture with air in open vessels, ether is always surrounded by an explosive atmosphere which is readily inflamed by the passage through it of an electric spark, either from the conductor of a machine, or from a Leyden jar. The result is rendered more interesting, when accomplished by a discharge from surfaces electrified by means of water, as in the experiment described page 26.

46. *Ignition of Inflammable Matter by the Electric Spark.—Ignition of Hydrogen with Oxygen.*

By means of a wire, insulated by being enclosed in a glass tube cemented into a socket, which screws into the touch-hole of the little cannon here represented, a spark from an excited conductor may be made to cross a small interval within the bore of the piece. Hence, if an explosive gaseous mixture of hydrogen with oxygen, or atmospheric air be made to occupy the cavity, and be secured by a cork, the mixture will explode on presenting the knob, K, of the insulated wire, to the prime conductor of the machine when in operation. It may be fired by the finger, or the nose of a person supported upon an insulated chair or stool, and communicating, at the same time, with the prime conductor sufficiently excited.

Of the Electrical Shock.

This effect of the electrical fluid is subsequently treated of in illustrating the mode of electrifying a patient.

Of Mitigating the Effects of Electricity.

The same charge of electricity, which would produce a shock or deflagrate a wire if received through a knob, may be insensibly received through a fine point. The power of an electrical machine, or that of a large battery is thus easily paralyzed. Hence the employment of pointed rods of metal as a protection against lightning. Hence, also, it is necessary, in the construction of electrical apparatus, to avoid all edges or acute projections, unless where it is intended to facilitate the passage of the fluid.

Rationale.—When a knob is approached to an excited conductor, as soon as any portion of it is near enough to be struck, so much of the ball is at hand as to allow the whole discharge to take place at once; but when the apex of a pointed wire is near enough to receive a portion of the fluid, the other parts are too remote to come into action; and whether the point advances to the electrified body, or the body approximates the point, the fluid is discharged before it is within striking distance of the thicker part of the wire.

In fact, the difference between a discharge by a point, and through a knob, resembles that which exists between making an auger-hole in a reservoir to let out a fluid, and opening a floodgate.

Of the proper Mode of constructing and putting up Lightning Rods.

The competency of pointed rods to protect us against lightning is dependent, not merely on the excellence of the point, which should be of platinum, but on the mode in which the joints in the conductor are made, and the nature of the soil in which it terminates. If a wire, pointed at one end, be blunt at the other, and the nearest conductor to the blunt end be not pointed, the charge will not pass off gradually because received at a point. Moreover, the power of a conductor to receive the electric fluid is compounded of its own conducting power, and that of the medium in which it terminates.

A metallic rod, terminating in a glass handle, in masses of sulphur or resin, or in dry sand, would not operate as a conductor. It cannot receive electricity, because it cannot deliver it.

Moist earth is but an imperfect conductor; since it owes its faculty of conducting to water, which, according to Cavendish, conducts with 200,000 times less facility than iron.

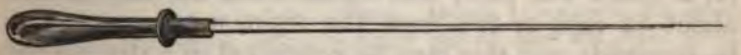
Lightning rods should, therefore, be connected, by soldering, with an extensive metallic surface buried under the earth; as, for instance, with sheets of lead or copper.

The cases in which conductors have been found incompetent, are, I am satisfied, referrible to their inadequate communication with the earth.

Thus is an important lesson given with respect to the means of protection against lightning. In vain do we employ for this purpose a conductor, however perfect, if it have communication with the earth only through a limited contact with the soil, which, being at best an imperfect conductor, may become an electric by desiccation.

I have surmounted the lightning rod by which my mansion is protected, by 17 copper wires pointed at one end, and at the other soldered into a hole drilled in the rod, which is constructed of iron. The juncture is surrounded by a globe of zinc of about two inches in diameter, above which the wires extend divergingly. The copper wires, by their association with zinc, are protected from oxidation; while their greater fusibility, as compared with the platinum point usually employed, is compensated by their number. The rod thus mounted rises about 10 feet above the apex of the roof, to the copper covering of which its lower end is soldered. The copper covering has an ample metallic connexion with the pipe for carrying off the rain, and this pipe with those of the public water works, all the joints being made with screws or solder. By these means a most ample communication with the earth is obtained. Analogous means should be employed in the case of all lightning rods, in situations where access can be had to a similar ramification of metallic pipes.

47. *Experimental Illustration.*



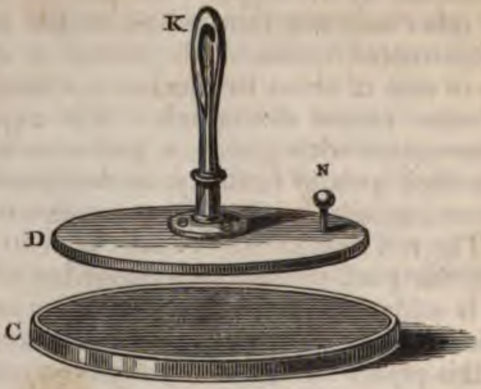
Effect of a point shown in drawing a charge from a battery or conductor:—proved, also, that its power is weakened or destroyed by being associated with an electric or imperfect conductor.

ADDITIONAL MEANS OF PRODUCING ELECTRICITY.

Of the Electrophorus.—Of Electricity evolved by the Friction of Caoutchouc.—Of Electricity evolved by Pressure.

48. *Of the Electrophorus.*

This is a peculiar instrument for the excitation of electricity, which we owe to the celebrated Volta. Electrical induction has already been explained (see 30); likewise the susceptibility of resinous substances to be electrified negatively by friction has been illustrated. The electrophorus is indebted for its efficiency to the co-operation of the effects of friction with the inductive power. By rubbing the cake of resin, C, with the fur side of a dry cat skin in a dry atmosphere, the resin is negatively elec-



trified. If the metallic disk, D, be placed upon the while thus excited, it will acquire a greater capaci receive electricity, in consequence of the proximity c negatively excited surface of the resin, as has al been explained in the instance of the condensing ele meter. Hence, if placed upon the resin with the a the glass handle, K, on applying the knuckle to the N, a spark will pass, and again when the disk is about an inch or two from the resin, another spar be received; and this may be continued in a dry air longer time than any operator would have patience t peat the operation. In dry weather, and in a dry a ment, an electrophorus will give sparks for many w without being again excited by friction. It was thr the aid of this property of his electrophorus, that was enabled to contrive an apparatus for the produ of instantaneous light, of which an engraving and des tion will be found in the section on Caloric.

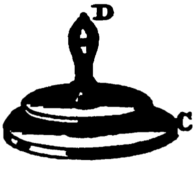
Of Electricity evolved by the Friction of Caoutchou

Dr. J. K. Mitchell has ascertained that in the su of a bag made of caoutchouc, or that of a thin she the same material stretched on a frame, there is a prising susceptibility of electric excitement. The at tive power, consequent to the excitation, appeared t peculiarly powerful.

Of Electricity evolved by Pressure.

There are many substances, especially gum elast caoutchouc, which, if placed upon the disk of an ele meter, and pressed, will, on the cessation of the pressure, evolve enough electricity to be indicated by the gold leaf.

49. *Evolution of Electricity from Caoutchouc by Pressure.*



C, cap of electrometer; D, handle of metallic disk, between which, and the cap of the single leaf electrometer, may be seen a piece of caoutchouc subjected to pressure. The disk being suddenly removed, the leaf will strike the ball as when otherwise electrified.

THEORETIC EXPLANATION OF ELECTRICAL PHENOMENA.

It may be proper to give the rationale of the production, accumulation, and neutralization of electricity, agreeably to the doctrine of two fluids.

This doctrine has, within the last thirty years, been gaining in credit, especially on the continent of Europe.

Of the Theory of two Fluids.

According to this hypothesis, when a body is electrically excited, a neutral compound, formed of two electrical fluids, is decomposed; one accumulates in the excited body, the other is evolved. That which accumulates in excited glass is evolved by excited resin; and vice versa, that which accumulates in resin is evolved by glass. Hence, according to this theory, the two electricities are always produced both by resin and glass; though the fluids accumulated in them respectively, being, in the first instance, separately recognised and associated with the substances in which they were observed, were named accordingly.

When, as in an electrical machine, a portion of a glass cylinder or plate is rubbed against a cushion, it gives off resinous and receives vitreous electricity. This surcharge of the vitreous fluid is retained by the excited surface, until, in revolving, it comes opposite to the collector.

The change of capacity, which caused the glass to eject the resinous and attract the vitreous fluid, ceasing with the friction to which it owes its existence, an equalization of the electricities between the glass and the conductor ensues; by which the excitement is reduced, more or less, according to the extent of their respective surfaces. Returning to the cushion, the glass is re-excited to the same extent as at first; and, by a continuation of the process, gradually causes an exchange of vitreous for resinous electricity between the conductors, until they are electrified as oppositely as the performance of the machine will permit.

Under these circumstances, if a conducting communication be made between the oppositely excited bodies, the electricities rush together, neutrality ensues, and a total cessation of electrical phenomena.

By some philosophers, the union of the two fluids is supposed to be productive of the evolution of heat and light. The inevitable consequence, that in separating they must absorb those elements, seems not to be sufficiently contemplated; nor indeed justified by any observed refrigeration between the surfaces of the cushion and electric, where the separation takes place.

In charging a Leyden jar, the two coatings become, for the time they are in communication with the conductors, respectively a part of them. That which touches the resinous or negative conductor, therefore, gives up its vitreous electricity, and receives resinous; while an opposite exchange of resinous for vitreous takes place in the other coating. Meanwhile the opposite electricities are supposed to exercise a reciprocal attraction through the glass, and are thus retained upon the surfaces which they respectively occupy. Of course a removal of the coatings does not cause a removal of the charge.

When the positive and negative surfaces of a charged pane act simultaneously on a metallic arch made to complete the circuit between them, the resinous electricity is attracted out of the end of the arc, near the coating vitreously charged, while the opposite effect takes place at the other end. Thus, by a series of decompositions and recompositions, or by currents passing each other, the different surfaces are restored to their previous state.

The principle of induction is much resorted to, agreeably to the doctrine of two fluids, to explain the passage of a spark between a body either vitreously or resinously excited, and one which is neutral. It is supposed that the fluids attract each other in all proportions, and in a way to bring into equilibrio the self-repellent power of the homogeneous atoms tending to dissipate the aggregate fluid, and the attraction of the heterogeneous atoms tending towards its accumulation. Yet it is conceived that the equilibrium is liable to be destroyed by the presence of a body surcharged with either electricity. If it be vitreous, by induction it repels the vitreous fluid from any mass in its vicinity, and attracts the resinous; if the surcharge be resinous, it repels resinous electricity, and attracts vitreous. When this species of reaction reaches a certain degree of intensity, the surcharge, and the heterogeneous electric matter, which, by the inductive process, has been accumulated in the neighbouring conductor, rush together, producing an electric discharge, and under favourable circumstances a spark or a shock.

Thus the unknown electric compound, formed by the union of the two electricities, is considered as liable to be decomposed by the proximity of either of its constituents in excess.

When of two portions of the same matter, one is remote, the other actually combined with a common object of attraction, I cannot understand wherefore the one should be displaced by the other.

Additional Remarks explanatory of Franklin's Hypothesis.

According to the theory of Franklin, the effect of an electrical machine in drawing electricity from the cushion, and accumulating it in the prime conductor, has some analogy with that of a wheel or pump for raising water.

The increased capacity for the electric fluid, arising from friction in the glass, operates like a bucket on a wheel, to enable it to receive a portion of fluid; and the loss of this capacity, after the friction ceases, is analogous to that inversion of the buckets which causes them to be emptied at every semi-revolution.

When the liquid thus raised is withdrawn from one reservoir to be thrown into another, so that the quantity in the former is diminished as much as it is increased in the latter, the effect is analogous to that of the cylinder or plate of an electrical machine in creating a surcharge in one of the surfaces of a pane at the expense of the other. Should the reservoirs be allowed subsequently to communicate by a syphon or sluice, and in consequence being on the same level, a previous equilibrium of pressure be restored, the office performed by the syphon would be analogous to that of a metallic arc in restoring the electrical equilibrium of the charged surfaces of a coated pane; excepting that the velocity of the electric current is incomparably greater.

In explaining the operation of charging a coated pane by the theory of Franklin, the incessant agency of the attraction between the fluid and the glass should be kept in mind. It is necessary to suppose an intense attraction to exist between the glass and the electrical particles; while between these particles there is an intense self-repulsion. When these forces are unimpeded, there can be no electric accumulation, because operating equally, they must produce an equal distribution of the electric fluid.

In a charged pane, this tendency to an equilibrium is counteracted by the impermeability of the glass, so that when by the operation of the machine, the fluid is abstracted from one side of the pane to be piled upon the other, the same attraction of the glass which resists the withdrawal of the fluid from the negative surface, retains it upon the positive surface as soon as it reaches it; while the surcharge thus retained, prevents any accession to the negative surface of electricity from other bodies. Thus an electrical surcharge in a coated jar or pane, is dependent on its attraction for the negative surface, and the repulsion between it and the electric matter in other bodies.

Rationale of Electric Light and Ignition.

It appears evident that there is a re-action between heat, light, and electricity.

It is not surprising, therefore, that the presence of one should cause the appearance of either of the others; since they all, evidently, pervade nature. It may be conjectured that the electric fluid is luminous when projected with intensity into the air, in consequence of its carrying along with it the light encountered in its progress through ponderable matter. In like manner it may cause the extrication of caloric, by displacing it when latent; or by adding temporarily to its repellent power, it may enable it to overcome the attraction of cohesion; in which case a metal, no doubt, contains caloric enough to produce a violent, or even explosive separation of the metallic particles.*

MEANS OF ELECTRIFYING PATIENTS EITHER WITH SPARKS OR BY SHOCKS.

50. *Electrifying with Sparks.*

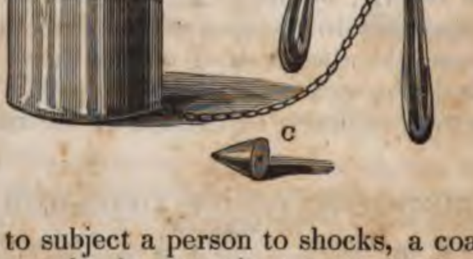
A person, seated on an insulated chair, is made to communicate with one of the conductors. Being thus nega-

---

* See sections on Caloric and Light.

tively or positively electrified, sparks may be taken from any part of the body, by a metallic knob or point. If the knob be too severe, the point may be used; and if this be too powerful, it may be covered by a wooden cone, C, represented in the following engraving.

51. *Apparatus for Electrifying by Shocks.*



In order to subject a person to shocks, a coated jar is used with two knobs; one in communication with the inside coating through the rod, R, which supports it, the other supported on an insulated wire, W, so that it may be made to approach or recede from the knob which communicates with the inner coating. To the outer coating and the insulated knob, chains are attached, each terminating at one end in a knob of metal with an insulating handle. The handles are held by the operator, and the knobs applied to the patient, so as to leave between them the part to be electrified. The coatings of the jar being severally connected with the different conductors of an electrical machine, the charge increases in the jar until it become strong enough to strike through the interval between the knob connected with the inner coating, and that insulated in its vicinity. Of course the height of the charge depends upon the interval thus left, according to the operator's discretion, or the feelings of the patient.

SECTION II.

CALORIC.

Experimental Proofs of the Existence of a material Cause of Calorific Repulsion.

It has been ascertained that ice melts and water freezes at the temperature of 32° of Fahrenheit's thermometer. If at this temperature, which is called the freezing point, ice in a divided state, as in that of snow for instance, be mingled with an equal weight of water at 172°, the ice will be melted, and the resulting temperature will be 32°; but if equal weights of water be mingled at those temperatures, the mixture will have the mean heat of 102°.

It follows that a portion of heat becomes latent in the aqueous particles during the liquefaction of the ice, sufficient to raise an equal weight of water one hundred and forty degrees. In this case the ice is supposed to combine with material calorific particles, innately endowed with a power of reciprocal repulsion, and likewise with that of combining with ponderable matter. Hence water is considered as a combination of ponderable particles, endowed with a reciprocally attractive power, and imponderable particles endowed with a reciprocally repellent power; so that, in obedience to the power last mentioned, the compound atoms, instead of cohering as in the solid state, move freely among each other, forming consequently a liquid.

In all cases of liquefaction or fusion which have been examined, analogous results have been observed; whence it is generally believed that whenever a solid is converted into a liquid, its particles unite with a portion of the material cause of heat, which becomes latent as in the case of ice in melting. The evidence is equally strong in favour of the inference that in passing from the liquid to the aëriform state, ponderable matter combines with, and renders latent even a larger quantity of heat in proportion to its weight, than in cases of liquefaction.

When, by means of a thermometer, we observe the rise of temperature in water exposed to a regular heat, as when placed in a cup upon a stove, we find that nearly equal increments of heat are acquired in equal times, until the boiling point is attained. Subsequently, the cup being open so as to allow the steam to escape freely, no further rise of temperature will be found to ensue; but in lieu of it, steam will be evolved more or less copiously, in proportion to the activity of the fire. Since from the time the water boils it ceases to grow hotter, it may be fairly presumed that the steam generated during the ebullition, although of a temperature no higher than 212°, contains, in a latent state, the caloric which meanwhile enters the liquid. This presumption is fully justified by the fact, that if any given weight of steam be received in a quantity of cool water ten times heavier, it will cause in it a rise of temperature of nearly one hundred degrees.

The heat which would raise ten parts of water to 100 degrees, would, if concentrated into one of those parts, raise it to 1000 degrees nearly, which is about equal to a red heat. It follows, therefore, that as much heat is absorbed in producing steam, as would render the water of which it consists red-hot, if prevented from assuming the aëriform state.

These facts and deductions induce chemists generally to believe that the cause of calorific repulsion is material; that it consists of a fluid, of which the particles are self-repellent, while they attract other matter; that by the union of this fluid with other matter, a repulsive property is imparted, which counteracts cohesion, so as to cause, successively, expansion, fusion, and the aëriform state;

and further, that it is by the afflux of the calorific matter that the sensation of heat is produced, while that of cold results from its efflux.

Acceptation of the term Caloric.

If we place a small heap of fulminating mercury upon the face of a hammer, and strike it duly with another hammer, an explosion will ensue so violent as to indent the steel. This explosion, agreeably to the premises, can only be explained by supposing the evolution of a great quantity of the material cause of heat. Were an equal quantity of red-hot sand to be suddenly quenched with water, the effect would be comparatively feeble. We may, therefore, infer that the fulminating powder, though cold, contains more of the cause of heat than a like quantity of red-hot sand. Hence it would follow from using the word heat in the sense both of cause and effect, that there is more heat in a cold body than in a hot one, which in language is a contradiction. On this account it was considered proper by the chemists of the Lavoisierian school, to use a new word, *caloric*, to designate the material cause of calorific repulsion.

52. *Experimental Illustration.*

A portion of fulminating mercury exploded between two hammers.

ORDER PURSUED IN TREATING OF CALORIC.

EXPANSION.—MODIFICATION OF THE EFFECTS OF CALORIC BY ATMOSPHERIC PRESSURE.—CAPACITIES FOR HEAT, OR SPECIFIC HEAT.—SLOW COMMUNICATION OF HEAT, COMPRISING THE CONDUCTING PROCESS AND CIRCULATION.—QUICK COMMUNICATION OF HEAT, OR RADIATION.—MEANS OF PRODUCING HEAT, OR RENDERING CALORIC SENSIBLE.—MEANS OF PRODUCING COLD, OR RENDERING CALORIC LATENT.—STATES IN WHICH CALORIC EXISTS IN NATURE.

EXPANSION.

OF THE EXPANSION OF SOLIDS, LIQUIDS, AND ELASTIC FLUIDS, AND ON THE OPPONENT AGENCY OF ATMOSPHERIC AND OTHER PRESSURE.

Expansion of Solids.

A ring and plug, which when cold fit each other, cease to do so when either is heated; and a tire when *red-hot* is made to embrace a wheel otherwise too large for it.

53. *Pyrometer, in which the Extension, in length, of a Metallic Bar is rendered sensible by a Combination of Levers.*

The influence of temperature on the length of a metallic wire may be rendered evident by means of the instrument, of which fig. 1, in the opposite engraving is a representation.

WW, represents a wire, beneath which is a spirit lamp consisting of a long, narrow, triangular vessel of sheet copper, open along the upper angle, so as to receive and support a strip of thick cotton cloth, or a succession of wicks. By the action of the screw at S the wire is tightened, and by its influence on the levers, the index I is raised. The spirit lamp is then lighted and the wire enveloped with flame. It is of course heated and expanded, and, allowing more liberty to the levers, the index upheld by them falls.

By the action of the screw the wire may be again tightened, and, the application of the lamp being continued, will again, by a further expansion, cause the depression of the index; so that the experiment may be repeated several times in succession.

Since this figure was drawn, I have substituted for the alcohol lamp the more manageable flame of hydrogen gas, emitted from a row of apertures in a pipe supplied by an apparatus for the generation of that gas. See fig. 2.

If, while the index is depressed by the expansion, ice or cold water be applied to the wire, a contraction immediately follows so as to raise the index to its original position.

Metals are the most expansible solids, but some are more expansible than others.

The following table, abstracted by Turner from that furnished by Lavoisier, will show the increase of bulk obtained by glass and various metals in rising in temperature from 32° to 212°.

Names of Substances.	*Elongation when heated from 32° to 212°.*
Glass tube without lead, mean of three specimens	1-1115 of its length.
English flint glass,	1-1248
Copper,	1-581
Brass, mean of two specimens,	1-532
Soft iron, forged,	1-819
Iron wire,	1-812
Untempered steel,	1-927
Tempered steel,	1-807
Lead,	1-351
Tin of India,	1-516
Tin of Falmouth,	1-462
Silver,	1-524
Gold, mean of three specimens,	1-602
Platinum, determined by Borda,	1-1167

Pyrometers have been made of platinum, in one of which, invented by Daniell, changes in the length of a cylinder of this metal, arising from temperature, are made sensible by the motion of a lever associated with it, and which acts as an index. In the other, a bulb is formed of platinum, and the degree of heat is inferred from the quantity of air expelled.

The use of this air pyrometer is burdened by the necessity of measurement and calculation to ascertain the result. This might be very much facilitated by the use of a sliding rod and air-gauge. The retraction of the rod might be made to compensate the expulsion of air, while divisions well made on it would indicate the quantity.

Instrument
for demonstrating the Power of Caloric in expanding a Metallic Rod.

Fig. 1.

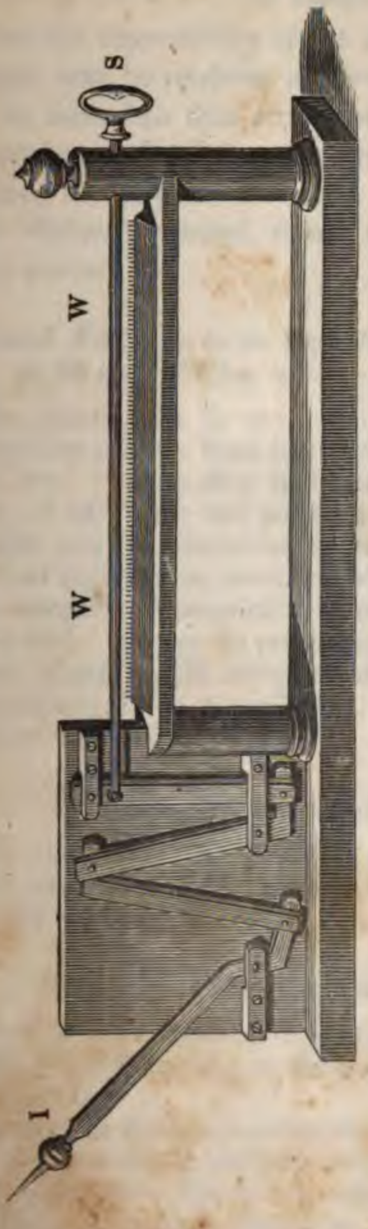
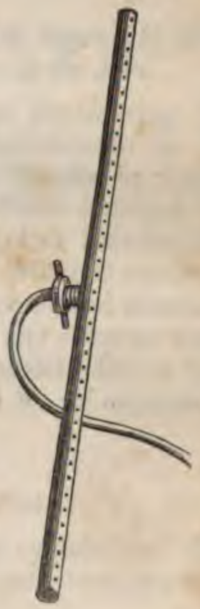


Fig. 2.



54. *Experimental Illustration of the different Expansibility of Metals.*

That the expansibility of one metal may exceed that of another, may be rendered apparent by soldering together, face to face, two thin strips, one iron the other brass. On exposure to heat, the compound strip, thus constituted, assumes the shape of an arch. The brass, which is the more expansible metal, forms the *outer* and of course *larger* curve.

Supposed Exception to the Law that Solids expand by Heat in the case of Clay, which contracts in the Fire.

The phenomena do not justify us in considering the contraction of clay from heat as an exception to the general law. In the first instance clay shrinks by losing water, of which the last portions are difficult to expel. In the next place a chemical union takes place between the principal ingredients, silica and alumina, which is rendered more complete in proportion to the duration and intensity of the fire. It may be presumed that the vitreous compound, which would result from a complete fusion and combination of the constituents, would be as expansible as other vitreous substances.

55. *Experimental Illustration.*

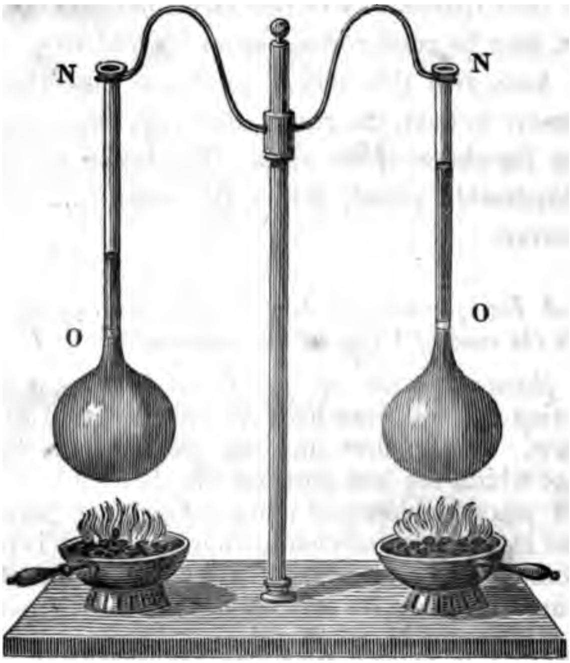
The contraction produced by heat in cylinders of clay shown by means of the ingenious but inaccurate pyrometer of Wedgwood.

Expansion of Liquids or non-elastic Fluids.

The word fluid applies to every mass that will flow, or distribute itself equally in obedience to its own weight or self-repulsion.

Ponderable fluids are either elastic or non-elastic. Latterly the term *liquid* has been employed to designate those fluids which are, like water, alcohol, and oil, devoid of elasticity, a property which, in due time, I shall define and illustrate.

56. *Liquids are expanded when their Temperature is raised, and some Liquids are more expansible than others.*



Let two globular glass vessels, with long narrow necks, as nearly as possible of the same size and shape, be supplied severally, with water and alcohol, excepting the necks from N N to O O, as represented in the above figure. Under each vessel, place equal quantities of charcoal, burning with a similar degree of intensity; or preferably, surround the bulbs simultaneously with hot water in an oblong vessel of suitable dimensions. The liquids in both vessels will be expanded so as to rise into the necks; but the alcohol will expand to a greater height than the water.

The dilatation of the following liquids, by a change of temperature from 32° to 212°, is as follows—alcohol 1-9, nitric acid 1-9, fixed oils 1-12, sulphuric ether 1-14, oil of turpentine 1-14, sulphuric or muriatic acid 1-17, brine 1-20, water 1-23 nearly, mercury about 1-55.

The rate of expansion for liquids increases with the temperature; as if their particles, by becoming more remote, lost some of their ability to counteract the repulsive influence of caloric.

The number associated with each of the substances in the following list, shows its melting point as estimated by Fahrenheit's scale. One degree of Daniell's pyrometer,* by which the temperatures above 600° were measured, is calculated to be equal to seven of Fahrenheit.

Cast iron 3479°, gold 2590°, silver 2233°, brass 1869°, antimony 810°, zinc 648°, lead 606°, bismuth 497°, tin 442°, sulphur 218°, beeswax 142°, spermaceti 112°, phosphorus 108°, tallow 92°, olive oil 36°, milk 30°, blood 25°, sea water 27½°, oil of turpentine 14°, mercury—39°, nitric acid—45½°, sulphuric ether—46°.

Exception to the Law that Liquids expand by Heat.

The bulk of water diminishes with the temperature, until it reaches 39° nearly. Below this point, it expands as it grows colder, and in freezing increases in bulk one-ninth. This wonderful exception to the law that liquids expand by heat, appears to be a special provision of the Deity for the preservation of aquatic animals; for were water to increase in density as it approaches the point of congelation, the upper stratum would continue to sink as refrigerated in bodies of water below 39°, as well as in others. Hence a whole river, lake, or sea might, in high latitudes, be rendered too cold for animal life; and finally be so far converted into ice, as not to thaw during the ensuing summer. Subsequent winters co-operating, the whole might become irretrievably solid. But in consequence of the peculiarity in question, the coldest stratum, in a body of water below 39°, remains at top, until, if the cold be adequate, congelation ensues. The buoyant sheet of ice, which results in this case, forms effectively a species of winter clothing to the water beneath it; and, by augmenting with the frost, opposes an increasing obstacle to the escape of caloric from the water which it covers.

Expansion of Aëriform Fluids.

Aëriform fluids are much more expansible than liquids. In order, however, to appreciate the changes of bulk which they may be observed to sustain, it is necessary to understand the influence which the pressure of the atmosphere has upon their density, independently of temperature. The simple influence of heat, in expanding them, may be illustrated by holding a hot iron over the thermometer of Sanctorio, represented in the following figure.

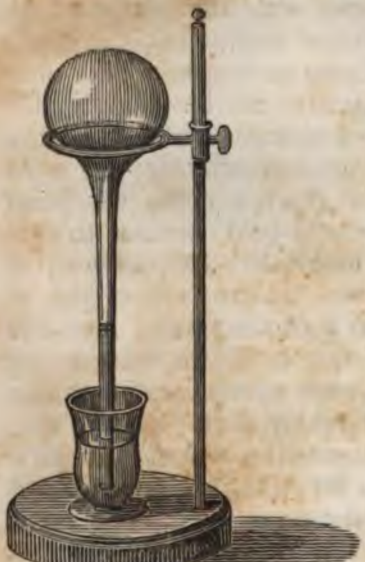
---

* See notice of this pyrometer, page 58.

Thermometers.

The invention of the thermometer is ascribed to Sanctorio. The principle of that form of the instrument which he contrived may be understood from the following article.

57. *Expansion of Air illustrated by the Air Thermometer of Sanctorio on a large Scale.*



The bulb of a matrass is supported by a ring and an upright wire with its neck downwards, so as to have its orifice beneath the surface of the water in a small glass jar. A heated iron being held over the matrass, the contained air is so much increased in bulk, that, the vessel being inadequate to hold it, a partial escape from the orifice through the water ensues. On the removal of the hot iron, the residual air regains its previous temperature, and the portion expelled by the expansion is replaced by the water.

If in this case the quantity of air expelled be so regulated, that when the remaining portion returns to its previous temperature, the liquid rises about half way up the stem, or neck, the apparatus will constitute an air thermometer. For whenever the temperature of the external air changes, the air in the bulb of the matrass must, by acquiring the same temperature, sustain a corresponding increase or diminution of bulk, and consequently, in a proportionate degree, influence the height of the liquid in the neck. As elastic fluids are dilated equably, in proportion to the temperature, and are also much more expansible than liquids, this thermometer would be very accurate, as well as pre-eminent in sensibility, were it not influenced by atmospheric pressure as well as temperature. On this account, however, it was never of much utility. Subsequently liquids were resorted to, and the instrument assumed the form now generally employed, the principle of which is explained by experiment 55, page 60.

In the following pages I shall give engravings and descriptions of the form of the thermometer used in the laboratory, of the self-registering thermometer, of the differential thermometer, and of an apparatus which illustrates the difference between it and Sanctorio's thermometer.

Agreeably to the example of my predecessor and preceptor Dr. Woodhouse, I have been accustomed to exhibit to my class the blowing and filling of a thermometer. Of this process an account is subjoined.

The tubes used in constructing thermometers are made at almost all the glass houses, having usually a capillary perforation. They are made by rapidly drawing out a hollow glass globe while red hot, by which means it is changed into a long cylindrical string of glass, in the axis of which a perforation exists, in consequence of the cavity of the globe.

When a thermometer tube is softened by exposure to a flame, excited by a blowpipe, a bulb may be blown upon it.

While the bulb is still warm, the other end of the tube is immersed in mercury, or in spirit, according to the purposes for which the instrument is intended. As the bulb cools, the air within it contracts, and thus allows the liquid to enter, in obedience to the pressure of the atmosphere. The bulb thus becomes partially supplied with the liquid, which is next boiled in order to expel all the air from the cavity of the bulb and perforation. The orifice being again depressed into the liquid, when the whole becomes cold the liquid will fill the cavity of the bulb. This result will be hereafter fully explained and illustrated.

The open end of the tube being now heated, is drawn out into a filament with a capillary perforation. The bulb being raised to a temperature above the intended range of the thermometer, so as to expel all the superabundant liquid, the point is fused so as to seal the orifice hermetically, or in other words so as to be perfectly air-tight.

In the next place, the bulb is to be exposed to freezing water, and the point to which the liquid reaches in the capillary perforation marked. In like manner the boiling point is determined, by subjecting the bulb to boiling water. The distance between the freezing and boiling points, thus ascertained, may be divided according to the desired graduation.

The scale of Reaumur requires 80 divisions, that of Celsius 100, Fahrenheit's 180. The graduation of Celsius is the most rational; that of Fahrenheit the least so, although universally used in Great Britain and the United States.

The degrees of these scales are to each other obviously, as 80, 100, and 180; or as 4, 5, and 9. Hence it is easy to convert the one into the other by the rule of three.

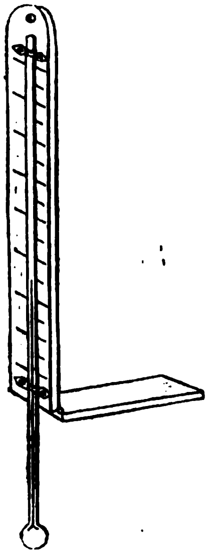
It should, however, be observed that the scales of Celsius and Reaumur commence at the freezing of water, all above that being plus, all below it minus; while the scale of Fahrenheit commences at thirty-two degrees below freezing. Hence in order to associate correctly any temperature noted by his thermometer with theirs, we must ascertain the number of degrees which the mercury is above or below freezing, and convert this number into one equivalent to it by their graduation; and conversely, after changing any number of degrees of theirs into his, we must consider the result as indicating the number of degrees above or below 32 on his scale.

The process above described for the construction of a thermometer, is equally applicable whether the bulb be filled with alcohol or mercury. Each of these liquids has peculiar advantages. Mercury expands most equably. Equal divisions on the scale of the mercurial thermometer will more nearly indicate equal increments or decrements of temperature. Mercury also affords a more extensive range; as it does not boil below 656°, nor freeze above—39°, of Fahrenheit's thermometric scale.

Alcohol boils at 176°, but has not been frozen by any cold, natural or artificial. Being more expansible than mercury, it is more competent to detect slight changes.

Besides those above mentioned, a thermometric scale has been used in Russia, which bears the name of its author, Delisle. In this, zero is at the boiling point of water, and five of his graduations are equal to six of Fahrenheit's.

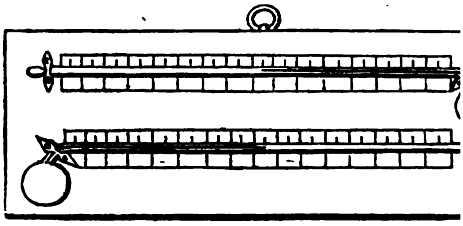
58. *Laboratory Thermometer.*



The thermometers used in laboratories, are usu
structed so as to have a portion of the wood o
which defends them from injury and receives
duation, to move upon a hinge, as in the adjoining
This enables the operator to plunge the bulb int
without introducing the wood or metal, which wou
be detrimental either to the process or to the inst
if not to both.

The scale is kept straight by a little bolt on the
it, when the thermometer is not in use.

59. *Self-registering Thermometer.*



This figure represents a self-registering thermometer.

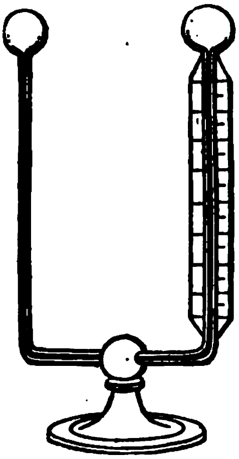
It comprises necessarily a mercurial and a spirit thermometer, which dif
those ordinarily used, in having their stems horizontal and their bores rou
large enough to admit a cylinder of enamel in the bore of the spirit therm
and a cylinder of steel in the bore of the mercurial thermometer. Both th
der of enamel and that of steel must be as nearly of the same diameter
perforations in which they are respectively situated, as is consistent wi
moving freely in obedience to gravity, or any gentle impulse.

In order to prepare the instrument for use, it must be held in such a situ
that the enamel may subside as near to the end of the alcoholic column as
yet still remaining within this liquid.

The steel must be in contact with the mercury, but not at all immersed i

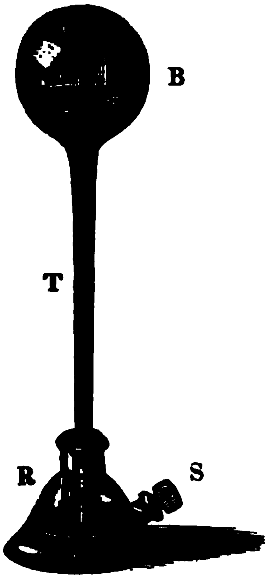
Under these circumstances, if, in consequence of its expansion by heat,
cury advance into the tube, the steel moves before it; but should the mer
tire during the absence of the observer, the steel does not retire with it.
the maximum of temperature, in the interim, is discovered by noting the gr
opposite the end of the cylinder nearest the mercury. The minimum of
ture is registered by the enamel, which retreats with the alcohol when it c
but, when it expands, does not advance with it. The enamel must retire
alcohol, since it lies at its margin, and cannot remain unmoved in the ab
any force competent to extricate it from a liquid, towards which it exerci
attraction. But when an opposite movement takes place, which does no
its extrication from the liquid necessary to its being stationary, the ena
not accompany the alcohol. Hence the minimum of temperature, which m
intervened during the absence of the observer, is discovered by ascertai
degree opposite the end of the enamel nearest to the end of the column of

60. *Leslie's Differential Thermometer.*



This instrument consists of a glass tube nearly in the form of the letter U, with a bulb at each termination. In the bore of the tube there is some liquid, as, for instance, coloured sulphuric acid, alcohol, or ether. When such an instrument is exposed to any general alteration of temperature in the surrounding medium, as in the case of a change of weather, the air in both bulbs being equally affected, there is no movement produced in the fluid; but the opposite is true, when the slightest change of temperature exclusively affects one of the bulbs. Any small bodies situated at different places in the same apartment warmed by a fire, will show a diversity of temperature, when severally applied to the different bulbs.

61. *Difference between an Air Thermometer and a Differential Thermometer illustrated upon a large Scale.*

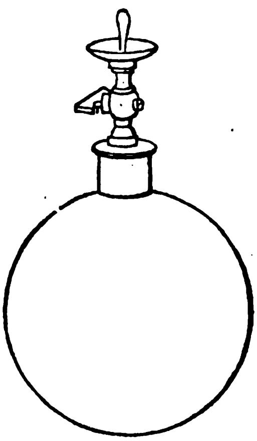


The adjoining figure represents an instrument, which acts as an air thermometer, when the stopple S is removed from the tubulure in the conical recipient, R; because in that case, whenever the density of the atmosphere varies either from changes in temperature, or barometric pressure, hereafter to be explained, the extent of the alteration will be indicated by an increase or diminution of the space occupied by the air in the bulb, B, and of course by a corresponding movement of the liquid in the stem, T. But when the stopple is in its place, the air cannot, within either cavity of the instrument, be affected by changes in atmospheric pressure: nor can changes of temperature which operate equally on both cavities, produce any movement in the liquid which separates them. Hence, under these circumstances, the instrument is competent to act only as a differential thermometer.

MODIFICATION OF THE EFFECTS OF CALORIC BY ATMOSPHERIC PRESSURE.

Digression to demonstrate the Nature and Extent of Atmospheric Pressure.

62. *Experimental Proof that Air has Weight.*



The air being allowed to replenish an exhausted globe, while suspended from a scale beam and accurately counterpoised, causes it to preponderate.

By a temporary communication with an air pump, by means of a screw with which it is furnished, a glass globe is exhausted of air. It is then suspended to one arm of a scale beam, and accurately counterpoised. Being thus prepared, if by opening the cock the air be allowed to re-enter the globe, it will preponderate; and if a quantity of water, adequate to restore the equilibrium, be introduced into a small vessel, duly equipoised by a counterweight applied to the other arm of the beam, the inequality in bulk of equal weights of air and water will be satisfactorily exhibited.

Definition of Elasticity.

The power which bodies have to resume their shape, position, or bulk on the cessation of constraint, is called *elasticity*. The degree in which any body possesses this power is not to be estimated by the force, but by the perfection of its recoil. A coach spring is far more powerful, but is not more elastic, than a watch spring.

Elasticity is erroneously spoken of as a varying property in the air, which, in common with aëriform fluids in general, appears to be always perfectly elastic.

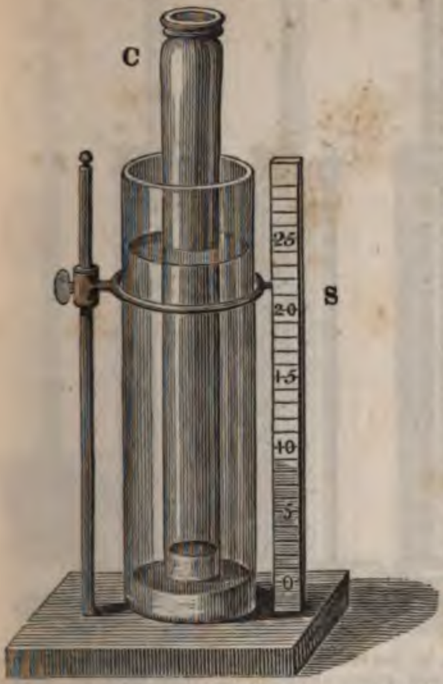
As a property distinguishing aëriform fluids from liquids, elasticity conveys the idea of a power in a given weight of a fluid to expand or to contract with the space in which it may be confined, producing at the same time a pressure on the internal surface of the cavity, or any object within it, inversely as the space.

The Existence and Extent of the Pressure of the Atmosphere experimentally demonstrated.

PRELIMINARY PROPOSITION.

For the pressure of any fluid on any area assumed within it, the pressure of a column of any other fluid may be substituted, making it as much higher as lighter, as much lower as heavier; or in other words, the heights are inversely as the gravities.

63. *Experimental Illustration in the case of Mercury and Water.*



If into a tall glass jar, such as is represented in the adjoining figure, a glass cylinder, C, (like a large glass tube open at both ends) were introduced—on filling the jar with water, this liquid would of course rise in the cylinder to the same height as in the jar; but, if, as in the figure, before introducing the water, the bottom of the jar be covered with a stratum of mercury, two inches deep, so as to be sufficiently above the open end of the cylinder, it must be evident that the water will be prevented from entering the cylinder by the interposition of a heavier liquid. But as the pressure of the water on the mercury outside of the cylinder is unbalanced by any pressure from water within the cylinder, the mercury within will rise, until, by its weight, the external pressure of the water is compensated. When this is effected, it will be seen, on comparing, by means of the scale, S, the height of the two liquids, that for every inch of elevation acquired by the mercury, the water has risen more than a foot; since the weight of mercury is to that of water, as 13.6 to 1.

It may be demonstrated that the pressure of the column of mercury is exactly equivalent to that of a column of water having the same base, and an altitude equal to that of the water in the jar, by filling the cylinder with water. It will then be seen, that, when the water inside of the cylinder is on a level with the water on the outside, the mercury within the cylinder is also on a level with the mercury without.

It is, therefore, obvious, that the elevation of the column of mercury, within the tube, is produced by the weight or pressure of the water without, and measures the extent of that pressure on the lower orifice of the tube.

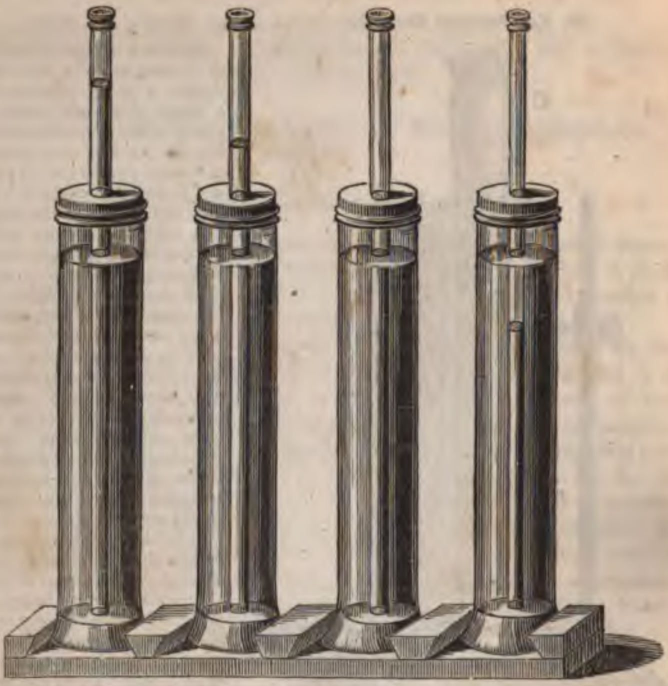
64. *The Illustration extended to the case of Liquids lighter than Mercury.*

Let there be four jars, each about four inches in diameter, and more than thirty inches in height, severally occupied by mercury to the depth of about two inches. In the axis of each jar, let a tube be placed, of about one inch and a half in diameter, and about one-fourth taller than the jar, with both ends open, and the lower orifice under the surface of the mercury. On pouring water into the jars, the mercury rises in the tubes, as the water rises in the jars; but the mercury rises as much less than the water as it is heavier.

The mercurial columns in this case, as in the preceding experiment, owe their existence to the pressure of the surrounding water, and by their height measure the extent of that pressure on the areas of their bases respectively. They may be considered as substituted severally for the aqueous columns, which would have entered the tubes had not the mercury been interposed. Accordingly, water being poured into one of the tubes, the mercury in that tube subsides to a level with the mercury without, when the water poured into the tube reaches the level of the water without.

The three remaining columns of mercury may be considered as substituted, in water, for columns of water, and being as much lower as heavier are found adequate to preserve the equilibrium.

It remains to be proved that other fluids, heavier or lighter than water, may in like manner be substituted for the columns of mercury, and of course for the water of which the mercury is the representative.



Into the three tubes, in which, by the addition of water to the jars, columns of mercury are sustained, pour severally, ether, alcohol, (differently coloured, so that they may be distinguished) and a solution of sulphate of copper, until the mercurial columns, within the tubes, are reduced to a level with the mercury without. It will be found that the column formed by the cupreous solution is much lower than the surface of the water on the outside of the tube; that the opposite is true of the column of alcohol; and that the ether, still more than the alcohol, exceeds the surrounding water in elevation.

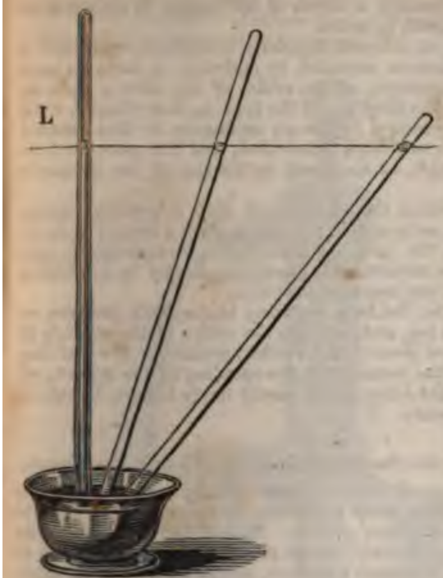
While it is thus proved that columns of mercury, ether, alcohol, and of a saline liquid may, in water, be substituted for columns of this liquid; it is also apparent that they must be as much higher as lighter, as much lower as heavier; or in other words, their heights must be inversely as their gravities; which will hereafter be more accurately proved by means of an instrument which I have contrived, called the litrameter.

65. *Torricellian Experiment.*

Pursuant to the law which has been above illustrated, that the pressure of one fluid may be substituted for that of another, provided any difference of weight be compensated by a corresponding difference in height; if, in lieu of water, the mercury were pressed by air on the outside of the tubes, unbalanced by air within, columns of the metal would be elevated, which would be in proportion to the height and weight of the air thus acting upon it.

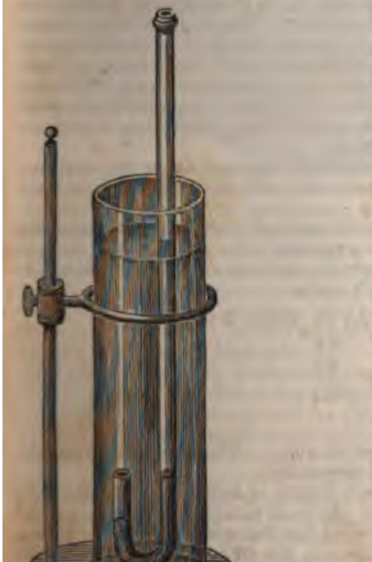
In order to show that the air exercises a pressure on the mercury outside of the tubes, analogous to that exercised by water in the experiments just described, it is only requisite that this external pressure be unbalanced by the pressure of air within the tube.

This desideratum is obtained by filling, with mercury, a tube about three feet in length, open at one end and closed at the other, and covering the open end with the hand, until it be inverted and merged in a vessel containing some of the same metal, without allowing any air to enter. A mercurial column of about 30 inches in height will remain in the tube, supported by the pressure of the surrounding air, and an index of its weight. This is a case obviously analogous to that of the mercurial columns, supported by the pressure of water in the experimental illustration above given.



The tube may be *supposed* to occupy either of the three positions, represented in the drawing. The mercury, in each position, preserves the same degree of elevation, its surface being always in the same horizontal plane, or level, whether upright or inclined. Or *we may suppose* three tubes, filled with mercury, and inverted in a vessel, nearly full, of the same metal, to be placed in the positions represented in the drawing. The upper surfaces of the columns of mercury in each tube, will be found always coincident with the same horizontal plane, however different may be the angle, which they make with the horizon. And the horizontal plane, in which their surfaces are thus found, will be between 28 and 31 inches above the surface of the mercury in the vessel. The line, L, with which the mercury in each of the tubes is on a level, represents a cord rendered horizontal, by making it parallel with the surface of the mercury in the reservoir.

66. *Additional Illustration of Atmospheric Pressure.*



I trust that the preceding illustrations are well adapted to convey a clear conception of atmospheric pressure; but as it sometimes happens, fortuitously, that when truth cannot get access to the mind under one form, it may reach it in another, even when less eligible, I subjoin the following illustration, which, though less amusing, and associating with it fewer instructive phenomena, is more brief, and perhaps equally conclusive.

If a tube, recurved into a crook at one end so as to form a syphon, with legs of very unequal length, and both ends open, have the crook lowered into water, as in the adjoining figure, the fluid will, of course, rise within the tube to the same height as without. But if, before the crook is sunk in the fluid, it be occupied by mercury, the water will enter the tube, only so far as the pressure which it exerts upon the mercury in the short leg of the syphon, is competent to raise the mercury in the long leg.

This pressure, or the effort of the water to enter the tube, is obviously measured by the height to which it forces the mercury, in the long leg of the syphon, above the mercurial surface in the short leg. The height will of course be greater or less, in proportion to the depth to which the lower surface of the mercury may be sunk. It will also be greater or less, according as the fluid in which it is immersed is heavier or lighter. Hence, as water is about 820 times heavier than air, a depth of 820 inches in air would displace the mercury as much as one inch in water.

Let us imagine a tube recurved at one end, similarly to the one represented in the foregoing figure, the crook likewise occupied by mercury, to have the upper orifice as completely above the atmosphere, as the orifice of the tube is above the water in the jar. The mercury, in the short leg of the syphon, thus situated, would be evidently exposed to a pressure, caused by the air analogous to that sustained from water, in the case of the tube, as already illustrated; and this pressure of the air would, as in the case of the water, be measured by the rise of the mercury in the long leg of the syphon.

It is obviously impossible to realize this experiment with a syphon reaching above the atmosphere; but, as the only motive for giving such a height to the syphon is to render the mercury in the long leg inaccessible to atmospheric pressure, if this object can be otherwise attained, the phenomenon may be exhibited in the case of the atmosphere without any material deviation.

In fact, to protect the mercury in the long leg from atmospheric pressure, we have only to seal the orifice of that leg, and, through the orifice of the other, to fill the syphon with mercury, before we place it in a vertical position. We shall then find that the pressure of the air on the mercury, in the open leg of the syphon, will support a column of this metal in the other leg of nearly thirty inches, though occasionally varying from 28 to 31 inches.

Inferences respecting the Weight of the Atmosphere from the preceding Experiments.

Supposing the base of the column of mercury, sustained by the atmosphere, as demonstrated in the preceding articles, were equivalent to a square inch, the total weight of the column would be about fifteen pounds. This of course represents the weight of that particular column of air only, whose place it has usurped; and as, for every other superficial inch on the earth's surface, a like column of air exists, the earth must sustain a pressure from the atmosphere, equal to as many columns of mercury, 30 inches high, as could stand upon it; or equal to a stratum of mercury of the height just mentioned, extending all over the surface of the globe.

It has been shown that the heights of heterogeneous fluids, reciprocally resisting each other, are inversely as their gravities; or, in other words, that they are as much higher as lighter, as much lower as heavier. The height of the column of air which, by its pressure, elevates the mercury, must, therefore, be as much greater than the height of the column of mercury, as the weight of the mercury is greater than the weight of the air, supposing the air to be of uniform density. Mercury is 11152 times heavier than air, and of course the height of the atmosphere would be (if uniform in density) 11152 × 30 inches = 27880 feet; supposing 30 inches to be the height of the mercurial column supported.

Hence the atmosphere, if of the same density throughout as on the surface of the earth, would not extend much above the elevation ascribed to the highest mountains.

But as the pressure of the atmosphere causes its density, it may be demonstrated that, the heights increasing in arithmetical progression, the densities will decrease in geometrical progression. Thus at an elevation of three miles, the air being, by observation, half as dense as upon the earth's surface:

At 6 miles it will be	$\frac{1}{4}$	At 21 miles it will be	$\frac{1}{128}$
9 - - - -	$\frac{1}{8}$	24 - - - -	$\frac{1}{256}$
12 - - - -	$\frac{1}{16}$	27 - - - -	$\frac{1}{512}$
15 - - - -	$\frac{1}{32}$	30 - - - -	$\frac{1}{1024}$
18 - - - -	$\frac{1}{64}$		

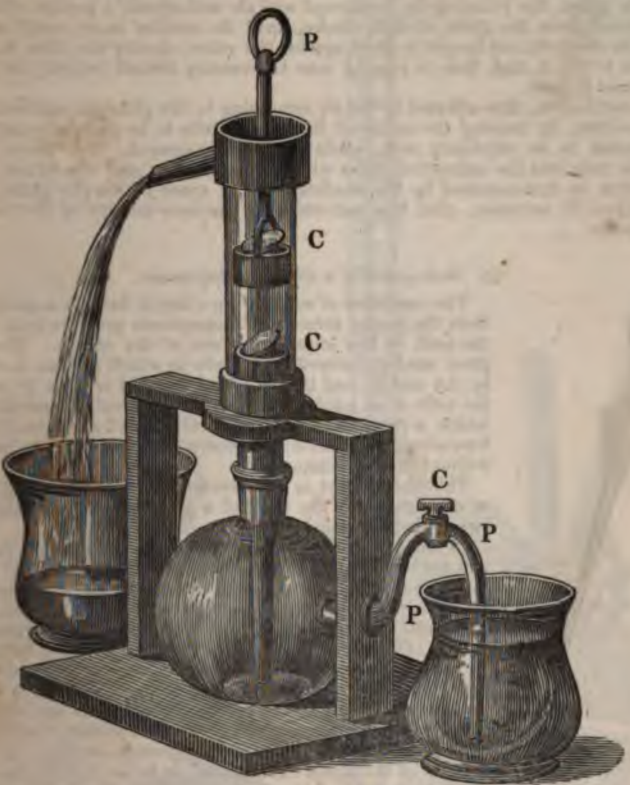
or rarer than we can render it by the finest air pump. These results have been verified, to a considerable extent, by actual observation.

It is reasonable to suppose that there is a degree of rarefaction, at which the weight of the ponderable particles of the air will be in equilibrio with the repulsive power of the caloric united with them. Beyond the distance from the earth's surface at which there should be such an equilibrium, the air could not exist. Hence it is inferred that the extent of our atmosphere is limited.

Of the Water Pump.

The admission of the atmosphere is necessary to the suction of the water from a receiver. *Air* may be removed from *close* vessels by the same process. Water rises by the pressure of the atmosphere; air presses out by its own elasticity.

67. *Mechanism and Action of the Suction Pump rendered evident by means of a Model with a Glass Chamber. Difference between pumping an Elastic Fluid and a Liquid, illustrated by an appropriate Contrivance.*



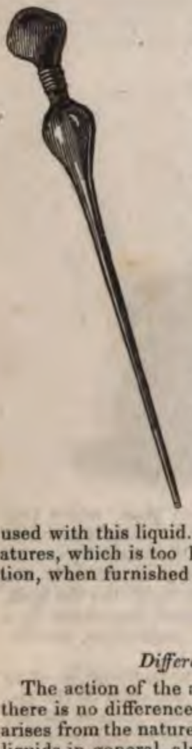
A little suction pump is constructed, with a chamber C C, of glass, which permits the action of its piston, P, and valves to be seen. Below the pump is a hollow glass globe filled with water. This globe communicates with the pump by a tube, visibly descending from the lower part of the pump, through an aperture in the globe, till it nearly reaches the bottom. This tube is luted air tight into the aperture by which it enters the globe. Its orifice, next the chamber, is covered by a valve opening upwards. In the axis of the piston there is a perforation, also covered by a valve opening upwards.

If the piston, P, be moved alternately up and down as usual in pumping, as often as it rises its valve will shut close; so that if nothing passes by the sides of the piston, nor enters into the chamber of the pump from below, a vacuum must be formed behind the piston. Under these circumstances, it might be expected that the water would rise from the globe through the lower valve, and prevent the formation of a vacuum. But being devoid of elasticity, and, therefore, incapable of self-extension beyond the space which it occupies, the water does not rise into the chamber of the pump, so long as by means of the cock, C, of the recurved pipe, P P, communication with the external air is prevented. But if this cock be opened during the alternate movement of the piston, a portion of the water will mount from the globe into the chamber at each stroke of the piston. The opening of the cock permits the atmosphere to press upon the fluid in the globe, and to force it up the tube leading to the pump chamber, as often as the chamber is relieved from atmospheric pressure by the rise of the piston.

As soon as the piston descends, the valve over the orifice of the tube shuts, and prevents the water from returning into the globe. It is of course forced through the perforation in the piston, so as to get above it. When the piston rises, the valve over its perforation being shut, it lifts the portion of water above this valve until it runs out at the nozzle of the pump; while the chamber, below the piston, receives another supply from the globe. But if after all the water has been pumped from the globe, the pumping be continued *with the cock closed*, a portion of air will be removed from the globe at each stroke, until the residue be so much rarefied, as, by its elasticity, no longer to exert against the valve, closing the tube, sufficient pressure to lift it, and thus to expand into the vacuity formed behind the piston, as often as it rises.

The rarefaction, thus effected in the air remaining in the globe, is rendered strikingly evident, by causing the orifice of the curved tube to be under the surface of some water in an adjoining vase, while the cock is opened. The water rushes from the vase into the exhausted globe with great violence; and the extent of the rarefaction is demonstrated by the smallness of the space within the globe which the residual air occupies, after it is restored to its previous density by the entrance of the water.

68. *Description of a Chemical Implement.*



The operation of sucking up a liquid through a quill, arises from the partial removal of atmospheric pressure from within the quill by the muscular power of the mouth. There is a great analogy between the mode in which suction is effected by the mouth, and that in which a liquid is made to rise into the bulb of an implement which I am about to describe, and which is very useful for withdrawing small portions of liquids from situations from which otherwise they cannot be removed without inconvenience.

This instrument is constructed by duly attaching a bag of caoutchouc to the neck of a glass bulb with a long tapering perforated stem.

In order to withdraw from any vessel into which the stem will enter, a portion of any contained liquid, it is only necessary to compress the bag so as to exclude more or less of the air from within it; then place the orifice of the stem below the surface of the liquid, and allow the bag to resume its shape. Of course, the space within it becoming larger, the air must be rarefied, and inadequate to resist the pressure of the atmosphere, until enough of the liquid shall have entered to restore the equilibrium of density between the air within the bag and the atmosphere. The air within the bag cannot, however, fully resume its previous density; since the column of the liquid counteracts, as far as it goes, the atmospheric pressure. Indeed, this counteracting influence is so great in the case of mercury, that the instrument cannot be used with this liquid. It is however the only substance, fluid at ordinary temperatures, which is too heavy to be drawn up into the bulb of the instrument in question, when furnished with a stout bag.

Of the Air Pump.

Difference between the Air Pump and the Water Pump.

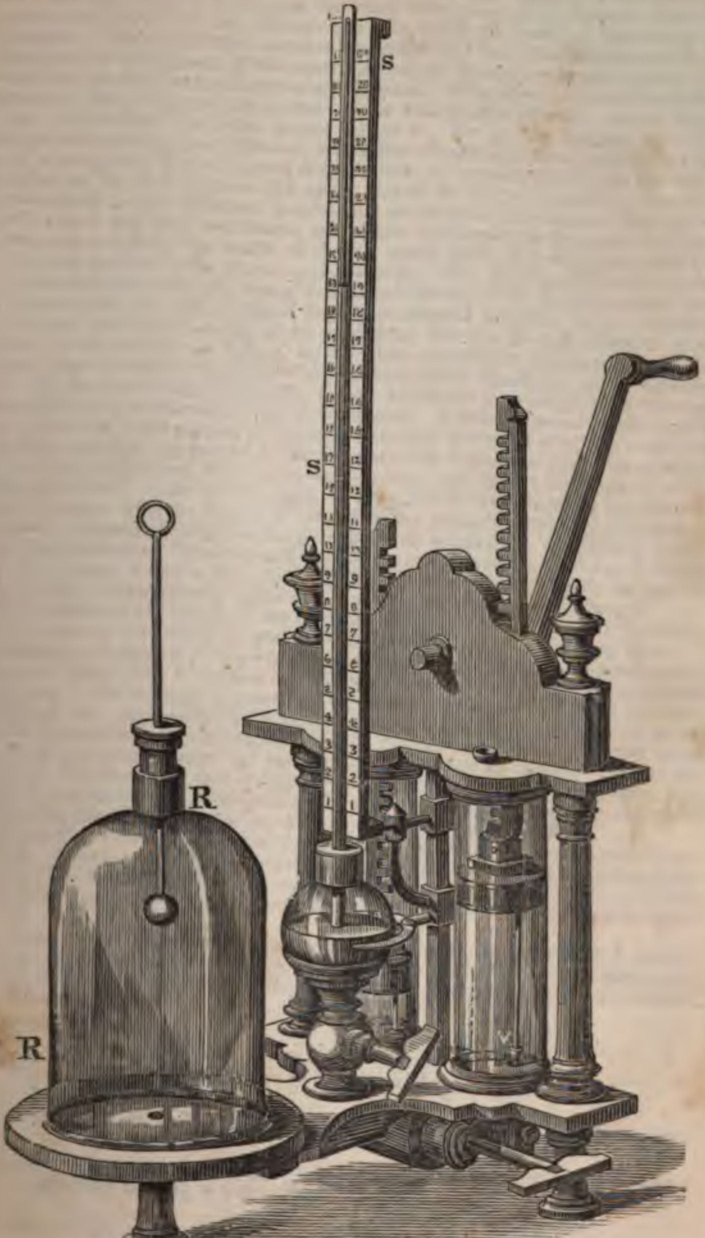
The action of the air pump is perfectly analogous to that of the water pump; as there is no difference between pumping water and pumping air, except that which arises from the nature of the fluids; the one being elastic, the other, in common with liquids in general, almost destitute of elasticity.

In the air pump, as in the water pump, therefore, there is a chamber, and an upper and lower valve, which operate in the same manner as the valves of the water pump already described.

69. *Description of a large Air Pump with Glass Chambers.*

The opposite engraving represents a very fine instrument of large size, obtained from Mr. Pixii, of Paris.

From the figure, it must be evident that this pump has two glass chambers They are unusually large, being nearly three inches in diameter inside. The lower valve, V, is placed at the end of a rod, which passes through the packing


S
S
R
R

the piston. Hence, during the descent of the piston, the friction of the packing against the rod, causes it to act upon the valve with a degree of pressure adequate to prevent any escape of air, through the hole which it closes, at the bottom of the chamber. The air included between the piston and the bottom of the chamber, is, therefore, by the descent of the piston, propelled through a channel in the axis of the piston, covered by a valve opening upwards. When the motion of the piston is reversed, the air cannot, on account of the last mentioned valve, return again into the cavity which the piston leaves behind it. But in the interim, the same friction of the packing, about the rod, which had caused it to press downwards, has now, in consequence of the reversal of the stroke, an opposite effect, and the valve V is lifted as far as a collar on the upper part of the rod will permit. The rise, thus permitted, is just sufficient to allow the air to enter the chamber through an aperture which the valve had closed, and which communicates by means of a perforation with a hole in the centre of the air pump plate, and of course with the cavity of the receiver, RR, placed over the plate. The reaction of the air in the perforation and pump chamber being diminished, the air of the receiver moves into the chamber until the equilibrium of density is restored between the two cavities. The chamber will now be as full of air as at first; but the air with which it is replenished is not so dense as before, as the whole quantity in the receiver and the chamber scarcely exceeds that which had existed, before the stroke, in the receiver alone. By the next downward stroke, the air which has thus entered the chamber is propelled through the valve hole in the piston. Another upward stroke expels this air from the upper portion of the chamber; and the valve attached to the rod being again uplifted, the portion of the chamber, left below the piston, is supplied with another complement of air from the receiver: and thus a like bulk of air is withdrawn at every stroke of the pump. I say a like *bulk* of air, since the *quantity* necessarily varies with the *density* of the air in the vessel subjected to exhaustion. This *density* is always directly as the *quantity* of air remaining; of course it finally becomes insignificant. Thus when the quantity, in the receiver, is reduced to one-hundredth of what it was at first, the weight of air removed, at each stroke, will be one-hundredth of the quantity taken at each stroke when the process began.

I have explained the action of one chamber only, as that of the other is exactly similar, excepting that while the piston of one descends, that of the other rises.

The gauge represented in the engraving, is one which I have contrived upon a well known principle. It consists of a globular vessel to hold mercury, supported upon a cock. The mercury is prevented from entering the perforation in the cock, by a tube of iron, surmounted by a smaller one of varnished copper, which passes up into a Torricellian glass tube till it reaches near the top. The glass tube opens at its lower extremity, under the surface of the mercury in the globe. The exhaustion of this tube, and that of any vessel placed over the air pump plate, proceed simultaneously, and consequently the mercury is forced up from the globe into the glass tube to an altitude commensurate with the rarefaction.

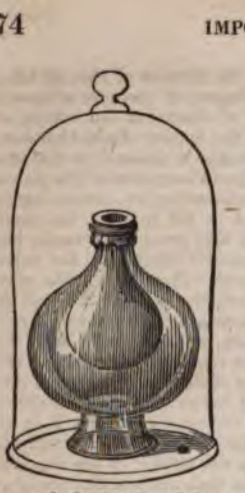
By inspecting a scale, SS, behind the glass tube, the height of the mercury is ascertained. In order to make an accurate observation, the commencement of the scale must be duly adjusted to the surface of the mercury in the globe. On this account it is supported by sliding bands on an upright square bar, between the glass cylinders.

The receiver, RR, represented on the air pump plate, is one which I usually employ in exhibiting the artificial aurora borealis. The sliding wire, terminated by a ball, enables the operator to vary the distance through which the electrical coruscations are induced.

Experimental Illustrations of the Elastic Reaction of the Air.

70. *Air occupying a small Portion of a Cavity, rarefied so as to fill the whole Space.*

Air is dependent on its own weight for its density, and enlarges in bulk in proportion as the space allotted to it is enlarged.

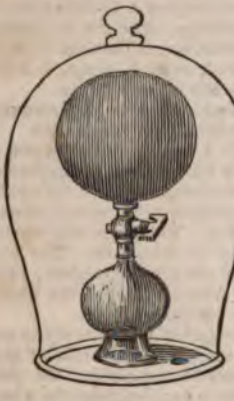


The mode in which the air occupying but a small part of a vessel may be rarefied so as to fill the whole cavity, is shown by the experiment represented in the annexed engraving. A bladder is so suspended within a vessel included in a receiver, as that the cavity of the bladder communicates through its own neck and that of the vessel, with the cavity of the receiver; while no such communication exists between the receiver and the space between the bladder and the inside of the vessel.

Things being thus situated, and the receiver exhausted, the bladder contracts in consequence of the removal of air from within it, proportionably with the exhaustion of the receiver; for, as the air between the outside of the bladder, and the inside of the vessel, is no longer resisted, within the bladder, by air of the same density, it expands into the space which the bladder had occupied, so as to reduce it into a very narrow compass.

This cannot excite surprise, when it is recollected that the air, confined between the outside of the bladder and the inside of the vessel, had previously to the exhaustion been condensed by supporting the whole atmospheric pressure, and must of course enlarge itself from its elasticity, as that pressure is diminished.

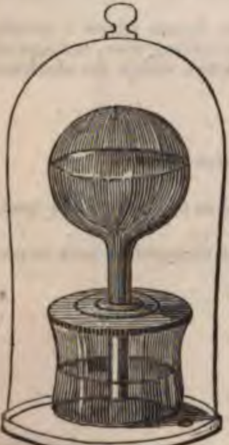
71. *Distention of a Caoutchouc Bag by the Rarefaction of confined Air.*



The power of any included portion of air to extend itself in consequence of a removal of pressure, is illustrated in another way, by subjecting to a highly rarefied medium a gum elastic bag, its orifice being previously closed, so as to be air-tight. The bag will swell up in a most striking manner, in proportion to the diminution of power in the air without the bag to counteract the reaction of the air within it.

The experiment is reversed by subjecting a bag, while inflated, to the influence of a condenser, by which it may be reduced in size more than it had been expanded; the air within the receiver being rendered denser than without.

In the adjoining cut, the gum elastic bag is represented as when inflated. The glass represented below the bag, is one which happened to be used as a support when the drawing was made.



72. *Expulsion of a Liquid by the Rarefaction of Air.*

A flask, half full of water, is inverted in another vessel, having some water at the bottom, and both are placed, under a bell glass, on the plate of an air pump. As the bell is exhausted by the action of the pump, the air included in the flask enlarges its bulk, finally occupying the whole cavity, and partially escaping from the orifice through the water in the lower vessel. When the atmosphere is allowed to re-enter the bell, the water rises into the flask, so as to occupy as much more space than at first, as the air occupies less, in consequence of a portion having escaped as abovementioned.

Experimental Proofs of the Weight of the Atmosphere.

73. *Atmospheric Pressure on the Hand.*

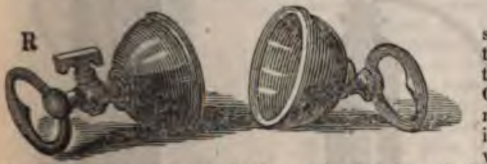
If, as represented in this figure, the air be exhausted from a vessel covered by the hand, its removal will be found almost impracticable: for, supposing the opening which the hand closes to be equal to five square inches, the pressure on it will be seventy-five pounds.

74. *Bladder ruptured by the Weight of the Atmosphere.*

Let there be a glass vessel open at both ends, as represented in this figure. Over the upper opening let a bladder be stretched and tied, so as to produce an air tight juncture. For every square inch of its superficies, the bladder thus covering the opening in the vessel sustains a pressure of about 15 pounds. Yet this is productive of no perceptible effect; because the atmosphere presses upwards against the lower surface of the bladder, as much as downwards upon the upper surface. But if the vessel be placed upon the plate of an air pump, so that, by exhaustion, the atmospheric pressure downwards be no longer counteracted by its pressure upwards, the bladder will be excessively strained, and usually torn into pieces.

When the bladder is too strong to be broken by the unassisted weight of the air, a slight score with the point of a penknife will cause it to be ruptured, not only where the score is made, but in various other parts, so that it will be, at times, torn all round from off the vessel.

75. *The Hemispheres of Otho Guericke, the celebrated Inventor of the Air Pump.*



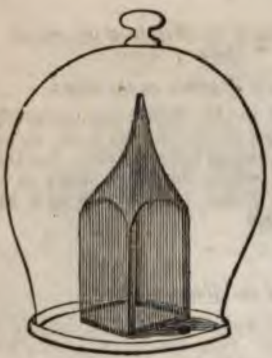
Two brass hemispheres are so ground to fit each other at their rims, as to form an air tight sphere when duly united. One of the hemispheres is furnished with a cock, on which is a screw for attaching the whole to the air pump. Being by these means exhausted, the cock closed, and the ring, R, screwed on to the cock, great force must be exerted by persons severally taking hold of the rings, before the hemispheres can be separated.

76. *Bottle broken by Exhaustion of the Air from within.*

Proof that a square glass bottle may be broken by atmospheric pressure on the outside, as soon as it ceases to be counteracted by the resistance of the air within.

The mouth of a square bottle being placed over the hole in an air pump plate, so as to be sufficiently tight for exhaustion, a few strokes of the air pump, by withdrawing the air from the interior, causes the bottle to be crushed.

A stout globular glass vessel, with an aperture at top, is placed over the bottle, to secure the spectators from the fragments.



77. *Bottle broken by Exhaustion of the Air from without.*

The elastic reaction of the air, confined within a square bottle, will burst it, as soon as relieved from the counteracting weight of the atmosphere.

If a thin square bottle, so sealed that while unbroken the contained air cannot escape, be placed within the receiver of an air pump, the exhaustion of the receiver will, by removing the pressure which counteracts the elastic reaction of the contained air, cause the bottle to be fractured.

78. *The Height of the Column of Mercury which balances the Atmosphere shown by Exhaustion.*

R, fig. 1, is a hollow glass cylinder, about 33 inches in height, and 2½ inches in diameter, into the upper end of which a brass gallows screw, G, is cemented; so that by means of the flexible pipe communicating with the air pump plate, A, the cylinder may be exhausted. The mouth of the cylinder being immersed in mercury in the vase, the metal, as the exhaustion proceeds, rises in the cylinder, until it reaches more or less nearly to the height at which it stands in a Torricellian tube, accordingly as the pump is more or less perfect.

FIG. 1.

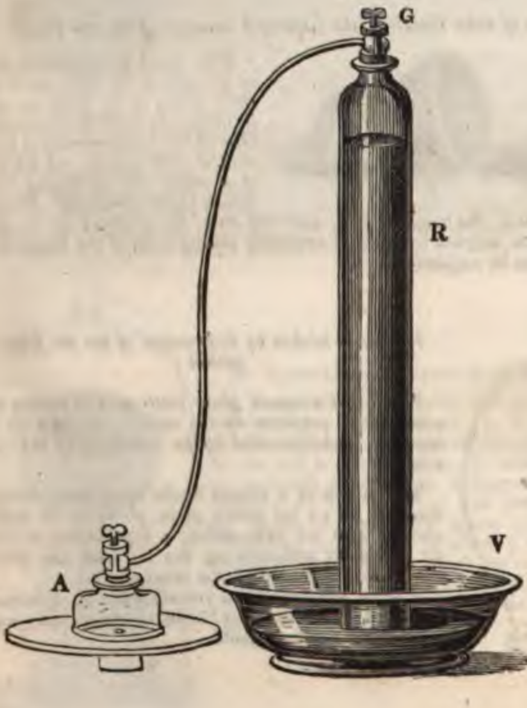


FIG. 2.

79. *Barometric Column of Mercury lowered by Exhaustion.*

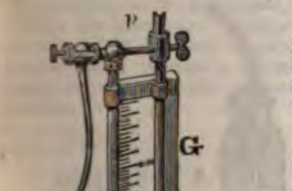
It has been shown that in a tube void of air, a mercurial column may be supported at the height nearly of thirty inches; and this has been alleged to result from the pressure of the atmosphere on the surface of the mercury on the outside of the tube.

In order to verify this allegation, let a tube, fig. 2, supporting within it a column of mercury, be placed under a competent receiver upon the air pump plate.

It will be found that, as the air is withdrawn from the receiver, the mercury in the tube will subside, and, if the exhaustion be carried far enough, will sink to a level with the mercury on the outside.

If, while this experiment is performing, a communication exist between the air pump and the cylinder, R, employed in the preceding experiment, the mercury will rise in the cylinder, while it falls in the tube; thus proving that the force which is required to remove the air from the outside of the tube and lower the mercury within it, is adequate to raise in the cylinder a mercurial column equal in height to that which is reduced.

80. *Of the Barometer Gauge.*



While I am upon the subject of atmospheric pressure, it appears to me expedient to give a description of an instrument which, in several of my illustrations, is employed to ascertain the quantity of air within a receiver.

It consists of a barometer tube, 33 inches in height, supported in a vertical position by a pedestal, and a strip of wood, G G. Attached to the latter is a brass scale, by which 30 inches is divided into 500 equal parts. The gauge tube is surmounted by a ferrule and gallows screw, by the aid of which a flexible leaden pipe, P, communicates with the bore of the tube. By means of the valve cock and gallows screw at V, this pipe may be made to communicate also with the cavity to be measured, the valve cock enabling us to suspend the communication when desirable. The lower orifice of the glass tube, T, is covered by mercury in a broad shallow receptacle, D. Supposing the cavity, under these circumstances, to be exhausted, and the communication with the bore of the glass tube open, the extent of the exhaustion, or, in other words, the quantity of air withdrawn, will be exactly in proportion to the rise of the mercury as indicated by the scale; and consequently, reversing the operation, the fall of the mercury, as indicated by the scale, will show the quantity of air which may be introduced. If we count the degrees upwards from the surface of the mercury in the receptacle, D, their number will show the quantity of air withdrawn. If we count the degrees downwards from the level of the top of the mercurial column in the barometer, the number will indicate the exact quantity of gas in the cavity examined. In short, the quantity taken out, or introduced, is always measured by the number of degrees which the mercury rises or falls in consequence. It is preferable to have two scales, one beginning above, the other below.

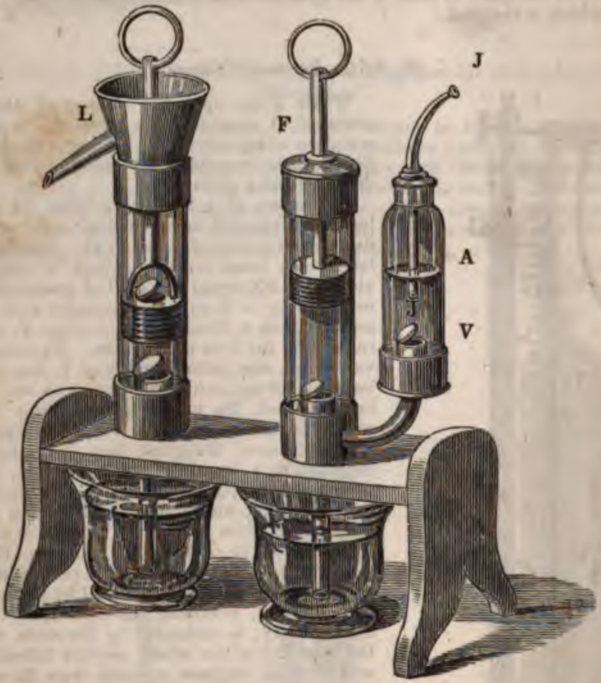
This gauge may be employed to indicate the quantity of air in any cavity. It only requires accuracy in the divisions of the scale, and in the adjustment of zero to the proper level. As the height of the mercurial column in the barometer varies with those changes of atmospheric pressure which it is employed to indicate, therefore, in counting downwards, care must be taken to place the commencement of the scale on a level with the upper end of a column of mercury in a good barometer, at the time. To facilitate this adjustment, I have occasionally placed a Torricellian tube by the side of the gauge tube. The top of the column of the mercury in the Torricellian tube is then the proper point for the upper zero. As the strip of wood to which the scale is attached slides upon the iron rod, R, the scale may be fixed at a proper height by a set screw.*

As the air pump will not produce a perfect vacuum, it is necessary, in order to wash out of a receiver all traces of atmospheric air, that successive portions of the gas to be substituted should be introduced and removed by exhaustion.†

The rise of the mercury in the tube, by diminishing the quantity in the receptacle, D, will cause the surface of it to be lower; but the breadth of this vessel is so great, and the descent of the mercurial surface in it so inconsiderable, that no error worthy of attention is thus produced.

It is proper to mention that the cavity of the tube ought to be so small in proportion to that of the receiver, as to create no error worthy of attention.

81. *Apparatus for illustrating the Difference between the Lifting and Forcing Pumps.*



The process by which the water is drawn into the chamber is the same in the case of the forcing as in that of the lifting pump. In the lifting pump, L, the water which has entered the chamber during the ascent of the piston, passes through the piston during its descent, and is lifted by it when the motion is reversed. In the forcing pump, F, the piston, being imperforate, forces, in descending, the water into the adjoining air vessel, A, whence its regress is prevented by a valve, V. The stroke being repeated, the water accumulates in the air vessel, compressing the contained air, until it reacts upon the water with sufficient force to cause an emission of this liquid through the jet pipe, J J, commensurate with the supply.

---

[*] Both the gauge tube and the rod, R, should be longer than they are represented in the figure.

[†] One gas may be employed to wash another out of a cavity, in a mode analogous to that in which water may wash out alcohol, or alcohol water.

Of Condensation.

It has been shown that, in consequence of the elasticity of the air, the quantity of this fluid, in any close vessel, may be diminished until the residual portion has, by the action of the air pump, become too rare to escape in opposition to the very slight resistance made by the valves. It remains to show that, in consequence of the same property, by an operation the converse of that of the air pump, the air in any adequate vessel may be made many times more dense than it would remain if liberated from confinement.

82. *Of the Condenser.*

The instrument employed for the purpose of condensing air is called a condenser.

The air pump was illustrated by its analogy with the suction pump. There is the same analogy between the condenser and the forcing pump. In the air pump, the valve between the chamber and receiver opens towards the chamber; in the case of the condenser a corresponding valve opens towards the receiver.

Besides the valve thus placed between the chamber and receiver, there is in each pump another valve. In the air pump, the air passes this second valve only when the piston moves so as to lessen the vacancy between it and the bottom of the chamber; in the condenser, the air passes only when the piston moves so as to enlarge the vacancy. In other respects these machines are so much alike, that the one might be used for the other. In my experimental illustrations, I shall have occasion to employ instruments which serve either to exhaust or to condense, according to the aperture selected for making a communication with the receiver.

FIG. 1.

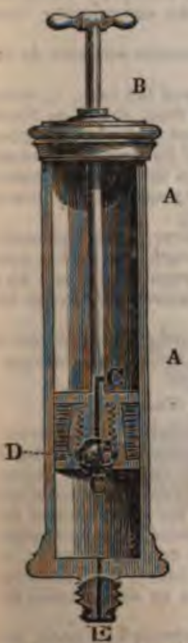


FIG. 2.

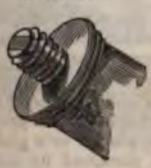


Fig. 1, in the adjoining engraving, represents the condenser. It consists of a brass cylinder, A A, ground internally, so as to be perfectly cylindrical. Into this a piston, B, is fitted by means of oiled leathers packed between screws, represented in the figure, and turned in the lathe, so as to enter the chamber in obedience to considerable force. At the lower end of the rod, a perforation, C C, may be seen, which commences at the lower extremity, rises vertically until it gets above the packing, and then passes out at right angles to its previous direction through the rod of the piston. Just above where it commences, a cavity, D, may be observed, which is left for the upper valve. This valve is formed of a strip of oiled leather tied over a brass knob represented within the cavity.

The upper and lower valves are exactly alike; hence, a good idea of either may be obtained from fig. 2, which affords a separate view of the lower valve.

The action of the condenser is as follows. When the piston is drawn up, all the air within the chamber gets below the packing through the perforation, C C, and the upper valve, which opens downwards with ease so as to afford a passage. When the piston descends, the air included in the chamber cannot get by the leather packing. The upper valve at the same time shuts so as to prevent it from getting through the perforation, C C. It has therefore to proceed through the lower perforation, E. The piston being drawn up again, the valve at E shuts and prevents a return of the air expelled, while the air of the chamber again gets below the piston as in the first instance. Thus, at every stroke, the contents of the chamber are discharged through the lower valve, while its retrocession from any receiver into which it may pass is prevented by the valve, E.

As the quantity of air in the vessel increases, the force requisite to drive the piston home becomes greater; and it has to descend farther, ere the air within the chamber exceeds in density that in the receiver, so far as to open the lower valve.

83. *Influence of Pressure on the Bulk of Air, and of its Density on its Resistance.*

Air lessens in bulk as the pressure which it sustains augments; and the resistance arising from its elasticity is augmented, as the quantity confined in the same space is increased, or the confining space diminished.

For the illustration of this proposition, I have devised the apparatus represented in the opposite engraving.

If mercury be poured into the air-tight vessel, A, through the tube, T T, which passes perpendicularly into this vessel until it touches the bottom; as the air in the vessel cannot escape, it is gradually reduced in bulk, but at the same time reacts upon the surface of the metallic liquid with a force which becomes greater, in proportion as its bulk is lessened. Hence an increasing mercurial column will be upheld, which by its height indicates the resistance. When the air in the vessel has been reduced to half its previous bulk, the height of the mercury in the tube will be about 30 inches, or equal to that of the mercury in the barometer at the time of performing the experiment. Thus it is shown, that when air is condensed into half the space which it occupies under the pressure of the atmosphere, its reactive power is doubled, being adequate to support a column of mercury equal to the pressure of the atmosphere, in addition to that pressure. It follows that the quantity of air occupying any space is as the compressing force, and is always to that of an equal bulk of the atmosphere, as the height of the column of mercury which it can support in a Torricellian tube is to the height of the mercury in the barometer: and likewise, that the resistance of included air increases with the diminution of the space allotted to it; or, vice versa, that the space which the same portion of air is capable of occupying, lessens as the compressing force increases.

It remains to be shown that the *resistance* of air to compression *increases* as the *quantity* in any space *increases*.

If, by means of the condenser, C, (the valve cock, *v c*, and the cock, *c*, being open,) air be injected into the vessels, A and B at the same time, it will be found that the liquid in the vase, V, will mount into the flask, F, and that when the pressure is adequate to cause the air in this to be reduced to half its previous volume, the mercury in the tube, TT, will have the same height as in the previous experiment; because the density of the air, and of course its quantity and reactive power, are doubled in one case no less than in the other.

The communication between the condenser and the receiver, A, is suspended during the first mentioned experiment, by closing the valve cock, *v c*. This cock is opened during the action of the condenser in the second experiment; and likewise another cock at *c*, which serves to intercept the communication between the condenser and the receiver, B.

See Appendix for an engraving, and description of the valve cock employed in this, and many other of my experiments requiring that there shall be no leakage.

84. *Mechanical Action of the Lungs in Respiration illustrated.*

The elevation of the sternum rarefies the air within the cavity of the thorax. Consequently, the atmospheric pressure not being adequately resisted, the external air rushes through the trachea into the lungs, dilating all the cells. The depression of the sternum and consequent diminution of the cavity cause the air which had thus entered, or an equivalent portion, to flow out. For the illustration of the process here described, I have contrived the apparatus represented in the next page.

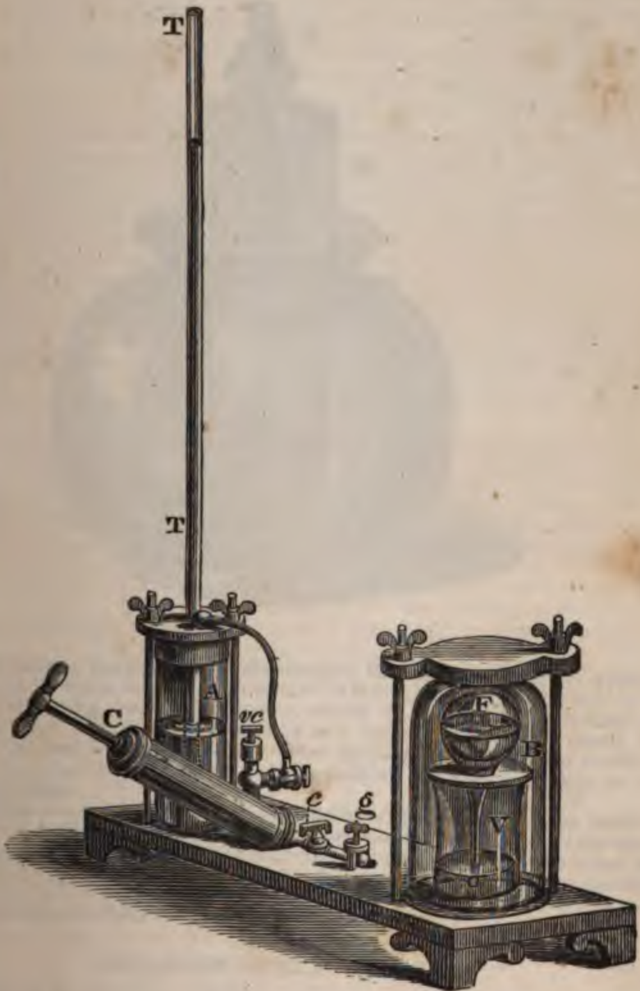
A tall receiver, R, with an orifice, O, is placed in a globe containing water, so that about two-thirds of the receiver are occupied by this liquid, the remainder with air, whilst a bladder is so suspended from the orifice as not to touch the water.

The atmosphere has access to the cavity of the bladder through its neck, and through the orifice O of the receiver, but not to the space A, between the outside of the bladder and the inside of the receiver.

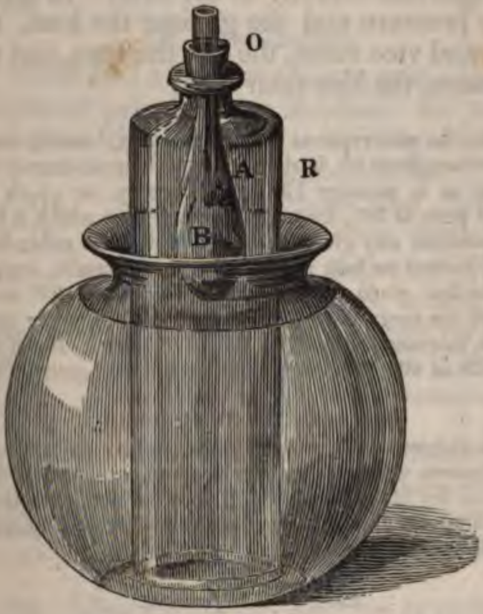
It may be assumed as an obvious consequence of the preceding experiments, (82, 83) that the pressure, exerted by any given quantity of air, is inversely as the confining space; or in other words, that the pressure increases as the space lessens, and diminishes as the space enlarges.

When a cavity to which the atmosphere has no access is enlarged, the density

Influence of Pressure on the Bulk of Air.



of the contained air is proportionably diminished. When any cavity is diminished, the density of the air is proportionably increased. But if the atmosphere, meanwhile, have access to the cavity, it will by its influx or efflux tend to preserve the equilibrium of density and pressure between the air of the cavity and the external medium. These consequences are well known to ensue, from an alternate enlargement and diminution of capacity, during the working of an air pump, a condenser, or bellows.



In like manner the elevation of the receiver, R, enlarging the cavity within it unoccupied by water, causes the air to rush in through the orifice, O; and the reversal of the motion, reducing the cavity, causes the air to rush out through the same aperture. The bladder is so situated as to receive all the air that enters, and to supply all that is expelled. Hence when the receiver is lifted, the bladder is inflated, and when lowered to its previous position, the bladder resumes its original dimensions.

Supposing the space, A, between the outside of the bladder and the inside of the receiver, to represent the space between the outside of the lungs and the inside of the thorax, the cavity of the bladder representing the cavities of the lungs, and the orifice, O, performing the part of the trachea and nostrils, the explanation, above given, will be as applicable to the apparatus by which nature enables us to breathe, as to that employed in the preceding illustration.

EXPANSION OF ELASTIC FLUIDS.

Having by means of the preceding digression explained the nature and extent of atmospheric pressure, I shall proceed to show the important influence exercised by it in all chemical processes in which elastic fluids are concerned.

It has been demonstrated (57) in illustrating the principle of Sanctorio's thermometer, that the bulk of the air in any space varies with the temperature.

It has been shown (70, 72, 83,) that the same effect may be produced by variations in atmospheric pressure.

It follows that the volume of elastic fluids is inversely as the pressure and directly as the heat. In other words, the less the pressure and the greater the heat, the larger their bulk; and vice versa, the less the heat, and the greater the pressure, the less their bulk.

Agreeably to the observations of Dalton, Gay-Lussac, and Crichton, 1000 parts of atmospheric air, in rising from the temperature of 32° to 212°, will expand so as to measure 1375 parts nearly, or $\frac{1}{480}$th of the bulk which it would have at 32°, for each degree of heat which it may receive.

Having, therefore, any given bulk of dry air, 100 cubic inches for instance at 60°, to find its bulk at any other temperature, suppose at 80°, we must in the first place consider that 480 parts at 32° would at 60°, adding one part for every degree above 32°, be 508 parts; and would by a proportionate increase, become at 80°, 528 parts. But if 508 parts at 60° become 528 at 80°, what will 100 parts at 60° gain by being heated to 80°.

$$508 : 528 :: 100 : 103.9$$

It has been inferred by the same distinguished philosophers, that all aëriform substances, whether gases or vapours, are expanded by heat at the same rate as dry atmospheric air, if they be not in contact with any vaporizable matter, in the liquid or solid state, which by vaporizing or condensing may vary the result.

Theory of Expansion.

The expansion of matter, whether solid, liquid, or aëriform, by an increase of temperature, may be thus explained.

In proportion as the temperature within any space is raised, there will be more caloric in the vicinity of the particles of any mass contained in the space. The more caloric in the vicinity of the particles, the more of it will combine with them; and in proportion to the quantity of caloric thus combined, will they be actuated by that reciprocally repellent power, which, in proportion to its intensity, regulates their distance from each other.

There may be some analogy between the mode in which each ponderable atom is surrounded by the caloric which it attracts, and that in which the earth is surrounded by the atmosphere; and as in the latter case, so probably in the former, the density is inversely as the square of the distance.

At a height at which the atmospheric pressure does not exceed a grain to the square inch, suppose it to be doubled, and supported at that increased pressure by a supply of air from some remote region; is it not evident that a condensation would ensue in all the inferior strata of the atmosphere, until the pressure would be doubled throughout, so as to become at the terrestrial surface, 30 pounds, instead of the present pressure of 15 pounds? Yet the pressure at the point from which the change would be propagated would not exceed two grains per square inch.

In like manner, it may be presumed that the atmospheres of caloric are increased in quantity and density about their respective atoms, by a slight increase in the calorific tension of the external medium.

Demonstration that Atmospheric Pressure opposes and limits Chemical Action, where Elastic Fluids are to be generated or evolved.

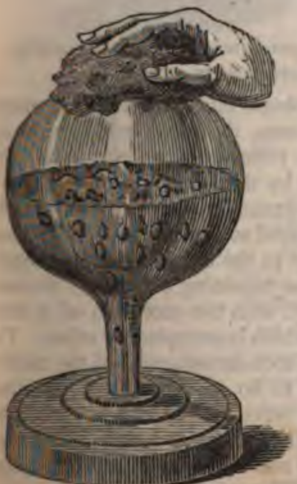
Of Vaporization.

Water would boil at a lower temperature than 212°, if the atmospheric pressure was lessened; for when it has ceased to boil in the open air, it will begin to boil again in an exhausted receiver. Those who ascend mountains find that for every 530 feet of elevation, the boiling point is lowered one degree of Fahrenheit's thermometer. It is, in fact, lowered or raised $\frac{176}{1000}$th of a degree for every tenth of an inch of variation in the height of the mercury in the barometer.

85. *Ebullition from diminished Pressure.*

The adjoining figure represents a vessel of water boiling within a receiver, in consequence of the diminution of pressure by exhaustion.

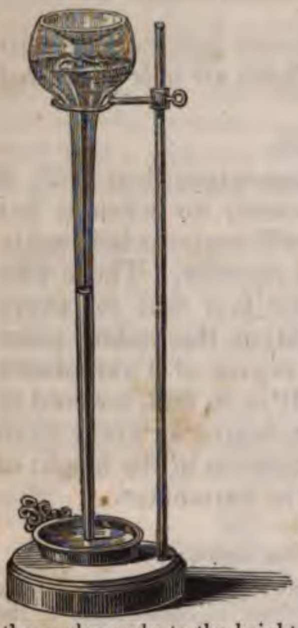
86. *Culinary Paradox.—Ebullition by Cold.*



A matrass, half full of water, being heated until all the contained air is superseded by steam, the orifice is closed so as to be perfectly air-tight. The matrass is then supported upon its neck, in an inverted position, by means of a circular block of wood. A partial condensation of the steam soon follows from the refrigeration of that portion of the glass which is not in contact with the water. The pressure of the steam upon the liquid of course becomes less, and its boiling point is necessarily lowered. Hence it begins again to present all the phenomena of ebullition, and will continue boiling sometimes for nearly an hour.

By the application of ice, or of a sponge soaked in cold water, the ebullition is accelerated; because the aqueous vapour which opposes it, is in that case more rapidly condensed; but as the caloric is at the same time more rapidly abstracted from the water by the increased evolution of vapour to replace that which is condensed, the boiling will cease the sooner.

87. *Improved Apparatus for showing the Culinary Paradox.*

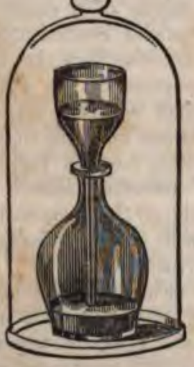


This figure illustrates a new and instructive method of effecting ebullition by cold.

The apparatus consists principally of a glass matrass, with a neck of about three feet in length, tapering to an orifice of about a quarter of an inch in diameter. The bulb is bulged inwards in the part directly opposite the neck, so as to create a cavity capable of holding any matter which it may be desirable to have situated therein. In addition to the matrass, a receptacle holding a few pounds of mercury is requisite. The bulb of the matrass being rather less than half full of water, and this being heated to ebullition, the orifice should be closed by the finger, defended by a piece of gum-elastic, and depressed below the surface of the mercury; the whole being supported as represented in the figure. Under these circumstances, the mercury rises as the temperature of the water declines, indicating the consequent diminution of pressure within the bulb. Meanwhile, the decline of pressure lowering the boiling point of the water, the ebullition continues till the mercury rises in the neck nearly to the height of the mercury in the barometer.

By introducing into the cup formed by the bulging of the bulb, cold water, alcohol, ether, or ice, the refrigeration, the diminution of pressure, and the ebullition, are all simultaneously accelerated; since these results are reciprocally dependent on each other.

88. *Experimental Proof that some Liquids would be permanently Aëriform, if Atmospheric Pressure were removed.*



The power of sulphuric ether to assume in vacuo, at ordinary temperatures, the aëriform state, in opposition even to the pressure of a column of mercury, may be shown by the following experiment.

A glass funnel is ground to fit air-tight into the neck of a glass decanter, so that the stem of the funnel may reach nearly to the bottom of the decanter, as represented in the adjoining cut. The decanter is filled with mercury, with the exception of a small portion of the neck which is occupied by ether. The stem of the funnel is then introduced into the neck of the decanter, so as to be air-tight; and the whole being included in a receiver, the air is withdrawn by a pump. The ether converted into vapour will force the mercury to rise from the decanter, through the stem, into the wider part of the funnel.

Rationale.—The attraction between the ponderable particles of the ether, and those of caloric, can be indulged only in opposition to the reciprocally repulsive power of the latter; since one tends to rarefy the caloric, the other to condense it into the limited space occupied by the ether. It follows that the caloric cannot combine with the ponderable matter beyond the point at which the repulsive power becomes equal to the attractive. But the repulsion exercised by the same number of particles of caloric will be greater as the space is less, and vice versa. The larger, therefore, the space occupied by the ponderable particles of the ether, the more caloric may combine with them, without rendering its reciprocally repulsive power paramount to its attraction for them.

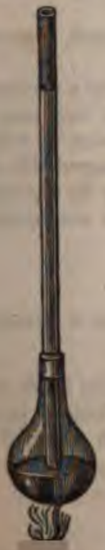
The removal of atmospheric pressure, by allowing the ponderable particles to occupy a larger space, enables them to combine with that additional quantity of caloric which is necessary to the aëriform state.

This explanation may, of course, be extended to the ebullition of other liquids in vacuo, at temperatures lower than those at which they boil in the air. It is obviously applicable to the two preceding illustrations.

89. *Boiling Point elevated by Pressure.*

Into a small glass matrass, with a bulb of about an inch and a half in diameter and a neck of about a quarter of an inch in bore, introduce nearly half as much ether as would fill it. Closing the orifice with the thumb, hold the bulb over the flame of a spirit lamp, until the effort of the generated vapour to escape becomes difficult to resist. Removing the matrass to a distance from the lamp, lift the thumb from the orifice. The ether, previously quiescent, will rise up in a foam, produced by the rapid extrication of its vapour.

This experiment may be performed with less risk, by plunging the matrass in hot water, instead of heating it by a lamp.



90. *Column of Mercury raised by Vaporized Ether.*

An increase of pressure results from ebullition, when the vapour produced by it is confined.

Having supplied a small flask with a small quantity of mercury and a minute portion of sulphuric ether; through the neck, let there be a glass tube, so introduced and firmly luted, as that it may be concentric with the vertical axis of the vessel, and extend downwards until nearly in contact with the bottom. If the flask, thus prepared, be held cautiously over a spirit lamp, the ether will be more or less converted into vapour. The vapour being unable to escape, will soon cause the mercury to rise to the top of the tube. On the removal of the lamp, the mercury will gradually fall to its previous situation.

91. *High Pressure Boiler.*

That the temperature of steam increases with the pressure, may be demonstrated by means of a small boiler, such as is represented in the opposite engraving.

The glass tube in the axis passes below the water in the boiler, and enters a small quantity of mercury at the bottom. The juncture with the tube where it enters the boiler is made perfectly tight. On the opposite side of the boiler, a tube, not visible in the engraving, descends into it. This tube consists of about two inches of a musket barrel, and is closed at bottom. The object of it is to contain some mercury, into which the bulb of a thermometer may be plunged for ascertaining the temperature.

When the fire has been applied during a sufficient time, the mercury will rise in the glass tube so as to be visible above the boiler; and continuing to rise during the application of the fire, it will be found that, with every sensible increment in its height, there will be a corresponding rise of the mercury in the thermometer. In front of the tube, as represented in the figure, there may be observed a safety valve with a lever and weight for regulating the pressure.

It has been found that, when the effort made by the steam to escape, in opposition to the valve thus loaded, is equal to about fifteen pounds for every square inch in the area of the aperture, the height of the column of mercury, C, C, raised by the same pressure, is about equal to that of the column of this metal, usually supported by atmospheric pressure in the tube of a barometer.

Hence the boiler, under these circumstances, is conceived to sustain an unbalanced pressure equivalent to one atmosphere; and for every additional fifteen pounds per square inch, required upon the safety valve to restrain the steam, the pressure of an atmosphere is alleged to be added. To give to steam at 212 degrees, or the boiling point, such an augmentation of power, a rise of 38 degrees is sufficient, making the temperature equal to 250 degrees. To produce a pressure of four atmospheres about 293 degrees would be necessary. Eight atmospheres would require nearly 343 degrees.

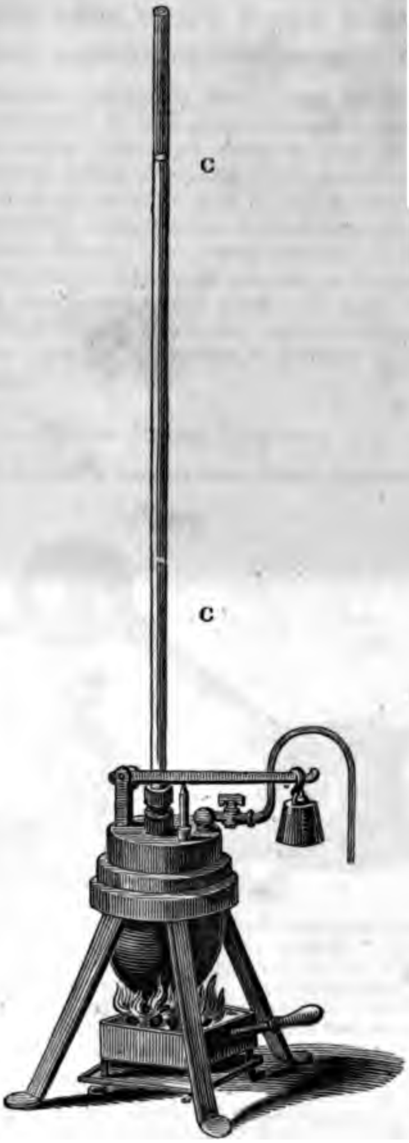
When by means of the cock an escape of steam is allowed, a corresponding decline of the temperature and pressure ensues.

If the steam, as it issues from the pipe, be received under a portion of water of known temperature and weight, the consequent accession of heat is surprisingly great, when contrasted with the accession of weight derived from the same source. It has in fact been ascertained that one measure of water, converted into aqueous vapour, will, by its condensation, raise about ten measures of water in the liquid form one hundred degrees.

Of the Incompetency of a Jet of High Steam to scald at a certain Distance from the Aperture.

Much attention has been excited by the observation, that the hands may be enveloped in a jet of vapour from a high pressure boiler without inconvenience, at a certain distance from the aperture through which it escapes.

High Pressure Boiler.



92. *Experimental Demonstration.*

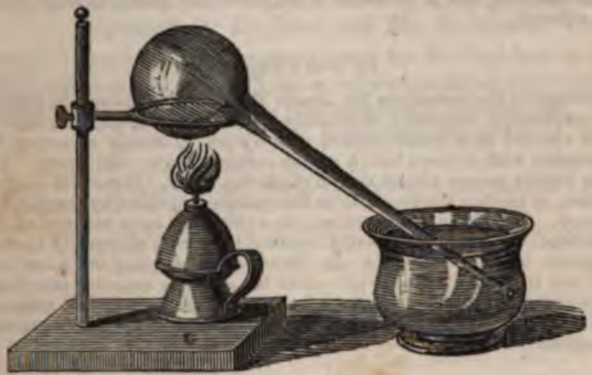
The fact that the hand may be immersed without injury in a jet of steam while issuing from a boiler, if not too near the aperture, experimentally demonstrated.

Rationale.—Since the temperature, density, and pressure, which form the distinguishing attributes of high steam, cannot be sustained without confinement, steam ceases to be ***high steam*** as soon as it is liberated. Consequently, a jet from a high pressure boiler is essentially no more than a copious jet of aqueous vapour at the heat of boiling water.

The only distinguishing characteristic, derived from its previously superior temperature and density, is a greater velocity of efflux. Without any superiority of temperature, the high pressure jet is propelled into the atmosphere with a momentum, which cannot be given to low steam. Hence the rapid refrigeration to which the former is subjected, at a sufficient distance from the place of its efflux to admit of an extensive diffusion in the atmosphere.

Of the Steam Engine.

93. *The principle of Savary's Steam Engine illustrated.*



A matrass, situated as in the preceding figure and containing a small quantity of water, being subjected to the flame of a lamp, the water by boiling, will soon fill the matrass with steam. When this is accomplished, bubbles of air will cease to escape from the neck of the matrass through the water in the vase.

The apparatus being thus prepared, the water of the vase, on removing the lamp, will quickly rush into the vacuity in the matrass, arising from the condensation of the steam.

Of Savary's Engine.

The celebrated engine of Savary, which led to the invention of that of Newcomen, and finally to the almost perfect machine of Boulton and Watt, consisted essentially of a chamber in which steam, after being introduced from a boiler, was condensed by a jet of cold water, as in the experiment above described.

Just before the condensation of the steam, the communication with the boiler was closed, and a cock, or valve, in a pipe descending into a reservoir of cold water, was opened. The chamber was consequently filled with water, which w[illegible]d

[illegible] allowing the steam to enter again
[illegible] the water escaped, and that through
[illegible] the operation of condensing
[illegible] was reiterated, as likewise in the
[illegible] stated.

[illegible]

[illegible] waste of steam arising from it
[illegible] is the power of cold water
[illegible] into the chamber [illegible]
[illegible] expelled until ebullition [illegible]
[illegible] being propagated [illegible]
[illegible] from above was not con

[illegible] engine of Savary, Newcomen
[illegible] condensation to act directly upo
[illegible] moving air tight in a large cylin
[illegible] to a large lever, to the end
[illegible] rod and weight were fastened
[illegible] piston, being exposed to th
[illegible] down to the bottom of th
[illegible] at the other end of the lever.
[illegible] weight on the beam at the en
[illegible] and at the same time drew
[illegible] by the alternate admission an
[illegible] were made to undergo an alternat
[illegible] was kept in operation. Althoug
[illegible] than by Savary's, there was sti
[illegible] the boiling point, each time tha
[illegible] that point, as often as condensa

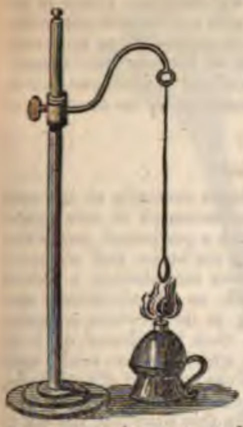
[illegible]

[illegible] Watt, who combined, in an uncommo
[illegible] knowledge, discovered that t
[illegible] it is only necessary to open
[illegible] by cold water. This bein
[illegible] latter. Hence his contrivance
[illegible] occupied by the piston as ofte
[illegible] at each reversal of the stro
[illegible] steam alternately above and be
[illegible] engine, the steam was actin
[illegible] steam is entering into the cylinde
[illegible] entered below, passes into th
[illegible] above the piston passes into th
[illegible] below the piston.

[illegible] Engine.

[illegible] of the high pressure engine
[illegible] alternately from above and be
[illegible]
[illegible] power: it is therefore
[illegible] than in engines working with
[illegible]
[illegible] principles, using
[illegible] per square
[illegible] of water
[illegible]

94. *Explosive Power of Steam.*



If a small glass bulb, hermetically sealed while containing a small quantity of water, be suspended by a wire over a lamp flame, an explosion soon follows, with a violence and noise which are surprising, when contrasted with the quantity of water by which they are occasioned.

Rationale.—Supposing that the bulb were, in the first instance, merely filled with steam, without any water in the liquid form, the explanation of this phenomenon would be comprised in the theory of expansion, given, page 82. In that case, the effort of the steam to enlarge itself, would be nearly in direct arithmetical proportion to the temperature; but when water is present in the liquid form, then, while the expansive power of the steam, previously in existence, is increased, more steam is generated with a like increased power of expansion. It follows that the increments of heat being in arithmetical proportion, the explosive power of the confined vapour will increase geometrically, being actually doubled as often as the temperature is augmented 38°. See page 86.

Interesting Experiments with respect to constrained Vaporization, by M. Cagniard De La Tour, and Mr. Perkins.

Agreeably to some experiments performed by M. Cagniard de la Tour, in which liquids were exposed to heat in very stout tubes, vaporization was performed in a space which was to that previously occupied,—

In the case of
- Ether, as 2 to 1, producing a pressure of 33 atmospheres.
- Alcohol, as 3 to 1, producing a pressure of 119 atmospheres.
- Water, as 4 to 1, producing a pressure greater than that caused by the alcohol.

Mr. Perkins alleges that a small iron boiler of great strength may be heated red hot while holding a portion of water, and that if, under these circumstances, an aperture be opened of ¼ of an inch in diameter, the steam will not escape, although upon a reduction of temperature, it will rush out with great violence.

It was inferred that the repulsion between the particles of the caloric in union with the water, and those in union with the metallic ring bounding the aperture, was paramount to the pressure tending to produce the expulsion of the steam.

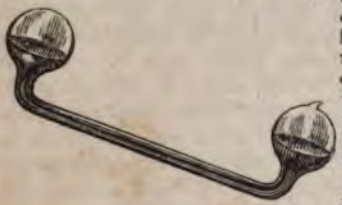
I am unable to reconcile this experiment with one which I performed by heating to incandescence, in a forge fire, a tube of iron, of which the bore was less than ¼ of an inch, while, by means of a cock, a communication with a high pressure boiler was made. Under these circumstances, the steam was not prevented from escaping through the pipe.

It appears to be sufficiently proved that the quantity of caloric combined with a given weight of steam is always the same, whatever may be its temperature; the sensible heat increasing and the latent heat diminishing as the density and pressure are augmented.

95. *Cold and Cloudiness arising from Rarefaction.*

Incipient rarefaction in the air of a receiver is usually indicated by a cloud, which disappears when the exhaustion has proceeded beyond a certain point. A delicate thermometer placed in the receiver, shows that a decline of temperature accompanies this phenomenon. We may, therefore, infer that the cloud is the consequence of refrigeration. If the suggestions be correct which were made (see page 82, Theory of Expansion) respecting the mode in which caloric exists in atmospheres around the particles of ponderable matter, it will not be difficult to understand why aëriform fluids should absorb more caloric, in proportion as their constituent particles are enabled, by a diminution of pressure, to become more remote. Hence, by rarefaction, the capacity of air is increased, and cold is produced, which condenses the aqueous vapour until its sensible heat is restored by an accession of caloric from the surrounding medium. See article 88.

96. *Cold produced by the Palm Glass.*



In forming the bulbs severally at the ends of the glass tube represented in this figure, one is furnished with a perforated projecting beak. By warming the bulbs, and plunging the orifice of the beak into alcohol, a portion of this liquid enters, as the air within contracts in returning to its previous temperature. The liquid, thus introduced, is to be boiled in the bulb which has no beak, until the whole cavity of the tube and of both bulbs, not occupied by liquid alcohol, is filled with its steam. While in this situation, the end of the beak is to be shortened and sealed, by subjecting it to the flame excited by a blowpipe.

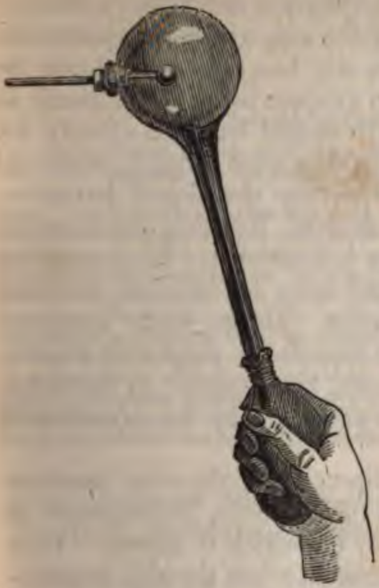
As soon as the instrument becomes cold, the steam which had filled the space, vacant of alcohol in the liquid form, condenses, and, with the exception of a slight portion of vapour, which is always emitted by liquids when relieved from atmospheric pressure, a vacuum exists within the bulb.

The instrument, thus formed, has been called a palm glass; because the phenomenon which it exhibits is seen by grasping one of the bulbs, so as to bring it completely into contact with the palm of the hand. One of the bulbs being thus situated, and while surcharged with the alcohol, and held in the position represented in the figure, both the liquid and vapour are propelled from it into the other bulb. This phenomenon combines the characteristics of the differential thermometer, (60,) with those of the culinary paradox, (86,) being the joint effect of the expansion, and evolution of vapour, in one part of the apparatus, and its contraction and condensation in another. The phenomena are precisely similar, whether we warm the lower bulb, or cool the upper one by means of ice. The motive for recurring to the experiment here is to state that, as soon as the last remnant of the liquid is forced from the bulb in the hand, a striking sensation of cold is experienced by the operator.

This cold is produced by the increased capacity of the residual vapour for caloric in consequence of its attenuation. The analogy is evident between this phenomenon and that above described, as taking place in the receiver of an air pump; both being attributable to the increase of capacity for caloric, resulting from a diminution of density.

97. *Cold consequent to Relaxation of Pressure.*

Cold is produced whether a diminution of density arise from relieving condensed air from compression, or from subjecting air of the ordinary density to rarefaction. A cloud similar to that which has been described as arising in a receiver partially exhausted, may usually be observed in the neck of a bottle recently uncorked, in which a quantity of gas has been evolved in a state of condensation by a fermenting liquor.



The apparatus represented in the annexed figure, shows the influence of relaxed pressure on the capacity of air for heat and moisture.

A glass vessel with a tubulure and a neck has an air thermometer fastened air tight by means of a cork into the former, while a gum elastic bag is tied upon the latter. Before closing the bulb, the inside should be moistened. Under these circumstances, if the bag, after due compression by the hand, be suddenly released, a cloud will appear within the bulb, adequate, in the solar rays, to produce prismatic colours. At the same time the thermometer will show that the compression is productive of warmth, the relaxation of cold.

The tendency in the atmosphere to cloudiness, at certain elevations, may be ascribed to the rarefaction which air inevitably undergoes in circulating from the earth's surface to such heights.

Of the Influence of the Atmosphere in promoting Evaporation.

It has been seen that by its pressure the atmosphere opposes vaporization; yet a free access of air is found indispensable in the desiccation of hay, or in the evaporation of water or other solvents. It was at one time generally conceived that evaporation resulted from an affinity between the liquid and the air, analogous to that between water and sugar, or alcohol and resin; but Dalton presented a different view of this subject, which is now generally approved. He has shown that whatever may be the temperature, no more vapour is formed during the presence of the air, than would be evolved in vacuo in the same space. It would seem from investigations made by that philosopher, by Gay-Lussac, and others, that a current of atmospheric particles promotes evaporation, only by removing the necessity to which the vapour would otherwise be exposed, of diffusing itself through the atmospheric interstices to a greater distance. Nevertheless, it appears to me that the influence of a current of atmospheric air, in promoting evaporation, is greater than can be reasonably accounted for upon the Daltonian doctrine; and I am at a loss to explain, consistently with this doctrine, wherefore spirits of turpentine and other essential oils, which, in the absence of the air, are less vaporizable than water, should, when the air has access to them, be comparatively more ready to evaporate. It is difficult to conceive that atmospheric air should have no affinity for vaporizable liquids: or that having such affinity, it should not in consequence, by attracting the liquid particles, promote the process of evaporation. Nothing can be more certain than that evaporation is accelerated in proportion to the extent to which contact may be induced between the aëriform and liquid particles. Hence when surfaces, moistened with such volatile liquids as sulphuret of carbon, or the more volatile ethers, are exposed to the wind, or to a blast, intense cold is produced by the accelerated evaporation.

It is well known that the direction of the wind becomes evident from the sensation of coldness, experienced in that part of the wetted finger on which it blows. With the refreshing influence of a breeze, when the skin is moistened by perspiration, we are all familiar. In these cases, the reduction of temperature must be ascribed to some property in the air which enables it to assist in the formation of vapour.

In fact the processes of evaporation, and vaporization in the sense of ebullition, cannot be confounded in practice, however they may be identified agreeably to prevailing theories. In either case heat is requisite, though much less is necessary in that of evaporation, but the process last mentioned is accelerated in proportion to the extent of surface exposed to the air. Ebullition takes place in proportion to the surface exposed to the fire without access of air. It only requires that the vapour generated should have an aperture sufficient to allow of its escape, without increase of pressure. Hence evaporating vessels are made broad and shallow, while boilers are made deep with narrow openings.

98. *Cold produced by the Evaporation of Ether when accelerated by a Current of Air.*

The cold, produced by evaporation accelerated by a current of air, may be advantageously shown by subjecting a thermometer bulb simultaneously to a jet of ether, and a blast from a bellows, so that the aërial and etherial particles may be thoroughly mingled just before reaching the bulb. Water may be frozen in a bulb thus refrigerated.

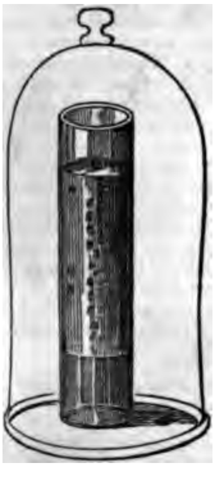
Definition of Vapour by Berzelius.

Berzelius objects to the use of the word vapour as implying a condensible aëriform fluid. He uses it in the sense in which English authors employ the word fog, or cloud. Vapour and steam were originally and still are used in English in this sense. Yet high steam, or low steam can apply only to that which the distinguished Swede would call aqueous gas. Johnson defines steam to be the smoke or vapour of any thing hot and moist. Of course steam, vapour, and smoke, in the old acceptation, were synonymous. In truth before Black's discoveries, as I have elsewhere stated, atmospheric air was the only aëriform fluid whose existence was recognised. Hence the use of the words steam and vapour has grown with our knowledge, and consequently the names applied to visible steam or vapour have been extended to mean the invisible aëriform fluids from which it is produced by refrigeration. I confess I have some repugnance to designating by a common epithet, permanent gases, and the condensible elastic fluids produced from liquids above their boiling points. I do not see that any disadvantage arises from the customary use of the word vapour to designate the latter.

Of the Opponent Influence of Pressure on the Extrication of Gaseous Substances from a state of Combination.

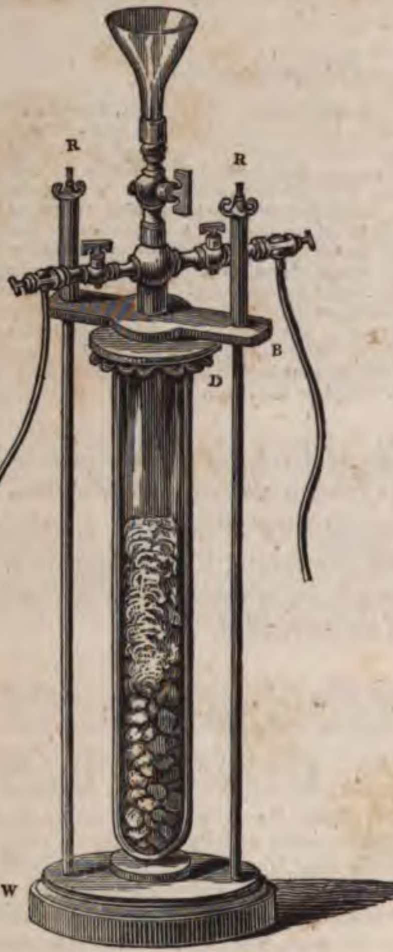
When one of the ingredients of a solid or liquid is prone to assume the aëriform state, its extrication will be more or less easily effected, in proportion as the pressure of the air is diminished or increased.

99. *Escape of Carbonic Acid from Carbonate of Lime subjected to an Acid, promoted by Exhaustion and checked by Condensation.*



If a tall cylindrical jar, containing a carbonate undergoing the action of an acid, be placed under a receiver, and the air withdrawn by an air pump, the effervescence will be augmented. But if, on the other hand, the same mixture be placed under a receiver, in which the pressure is increased by condensation, the effervescence will be diminished. In the one case, the effort of the carbonic acid to assume the gaseous state is repressed; in the other, facilitated. Hence the advantage of condensation in the process for manufacturing carbonic acid water. Beyond an absorption of its own bulk of the gas, the affinity of the water is inadequate to subdue the tendency of the acid to the aëriform state; but when, by exterior mechanical pressure, a great number of volumes of the gas are condensed into the space ordinarily occupied by one, the water combines with as large a volume of the condensed gas, as if there had been no condensation.

100. *Improved Apparatus for showing the Influence of Pressure on Eff*



A cylindrical
about 30 inches i
supported on a wo
W, between uprig
R R, fastened int
and at top cut into
nished with nuts.
of these screws ar
an intervening cr
brass disk, D, is p
the rim of the rec
disk is so fitted to
the glass, as tha
aid of sheet gun
oiled leather, a
juncture may be
the middle of the
is an aperture,
proceeds a stout
cock on each sid
furnished with gall
by means of whic
may be made to co
with an air pump
and a condenser o
The tube is also
by a cock, into w
funnel is cement
closing the receiv
disk, some carbon
or carbonate of am
be introduced, so
about half the he
receiver. I have
careous stalactites
from Weyer's cav
cellent for this pur
carbonate being
and the disk faste
place, as represe
figure, diluted m
may be added, by
the funnel and co
tity sufficient to
carbonate. Of c
vescence immedia
If, under these circ
by means of the ai
atmospheric pressure within the receiver be lessened, the effervescenc
strikingly. On the other hand, if, by closing the communication with th
and opening that with the condenser while this is in operation, the pre
creased, it will be seen that the effervescence is diminished proportional

This experiment is much facilitated and improved by my newly co
pump, by which we can either exhaust or condense at pleasure. (See

Of the Screw Rod and Plate Frame, employed in the preceding and ma Experiments.

The means by which the glass receiver, employed in the preceding e
is upheld and rendered air-tight by the rods R R, the wooden block, W
B, and circular plate or disk, D, is one to which I shall resort freque
course of my experiments. Hence, to avoid unnecessary recurrence to
d. I shall in future designate as *a screw rod and plate frame*, t

of the apparatus above described, which consists of the *block*, *bar*, *plate*, and *screw rods*.*

The glass in this case is made quite true by grinding on a large lap wheel, such as is employed by lapidaries. The same object is effected in the case of brass plates without grinding, by turning them in a lathe with a slide rest, and a tool with a fine pyramidal point.

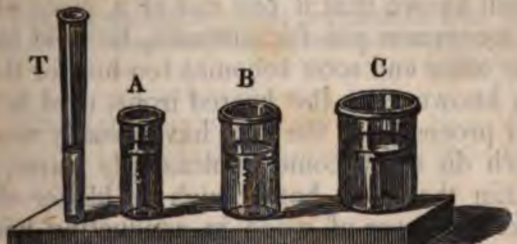
OF CAPACITIES FOR HEAT, OR SPECIFIC HEAT.

The power of equal weights of different substances, at the same temperature, in cooling or warming a liquid at a temperature different from their own, will be found very unequal. Thus the effect of a given weight of water being 1000, the effect of the like weight of glass will be 137, of copper 94, tin 51, lead 29, iron 110, gold 29, platinum 31, zinc 92, silver 55. If equal weights of water and mercury, at different temperatures, be mixed, the effect on the water will be no greater than if, instead of the mercury, $\frac{1}{28}$th of its weight of water, at the same temperature as the mercury, had been added; and it takes twice as much mercury by measure as of water heated to the same point to have the same influence.

The term specific heat is usually employed to designate the quantity of *caloric* in a body in proportion to its *weight* or *bulk*, as specific gravity is used to convey an idea of *weight* compared with *bulk*.

In the process above described, the specific heats of substances are found in order to estimate their capacities; the one being necessarily as the other, and the same series of numbers expressive of either.

101. *Apparatus for illustrating Capacities for Heat.*



Let the vessels A, B, and C, be supplied with water through the tube, T, which communicates with each of them by a horizontal channel in the wooden block. The water will rise to the same level in all. Of course the resistance made by the water in each vessel to the entrance of more of this liquid will be the same, and will be measured by the height of the column of water in the tube, T. Hence if the height of this column were made the index of the quantity received by each vessel, it would lead to an impression that they had all received the same quantity. But it must be obvious that the quantities severally received will be as different as are their horizontal areas. Of course we must not assume the resistance, exerted by the water within the vessels against a further accession of water from the tube, as any evidence of an equality in the portions *previously* received by them.

---

* Modifications of the screw rod and plate frame are represented in the engraving accompanying article 83.

In like manner the height of the mercury in the thermometer shows the resistance which substances, whose temperature it measures, are making to any further accession of caloric; but it does not indicate the quantities, respectively received by them, in attaining the temperature in question. This varies, in them, in proportion to their attraction for this self-repellent fluid; as the quantities of water received by the vessels, A, B, C, are varied in the ratio of their respective areas.

Rationale.—It may be conjectured that this diversity in the power of substances, equally hot or cold, in influencing temperature, is due to a difference in their capacity to attract caloric, in consequence of which it probably forms denser atmospheres about the atoms of some substances, than it does about those of others.

An analogy has already been suggested to exist between the manner in which these calorific atmospheres surround atoms, and that in which the earth is surrounded by the air; and also the mode has been suggested in which changes of temperature in the external medium would operate upon the density of such atmospheres. Supposing these preliminary suggestions correct, it would follow that the quantity of caloric absorbed or given out at each exterior change of temperature, by any one congeries of atoms, would be to that absorbed or given out by any other congeries, as the previous condensation of caloric in the one, is to its previous condensation in the other. See Theory of Expansion, page 82.*

OF THE SLOW COMMUNICATION OF HEAT, COMPRISING THE CONDUCTING PROCESS AND CIRCULATION.

Of the Conducting Process in Solids.

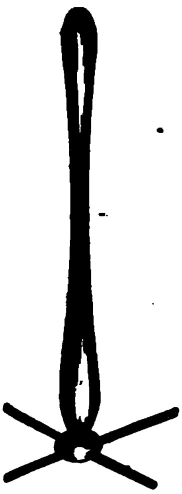
It is well known that if one end of a piece of metallic wire, as a common pin for instance, be held in a candle flame, the other end soon becomes too hot for the fingers. It is also known that the heated irons, used in soldering and other processes in the arts, have usually wooden handles, which do not become unpleasantly warm, when the irons within them are hot enough to blister the hands. This inferior power of wood in conducting heat is also well exemplified by the handles of silver tea-pots, which are sometimes altogether of wood; in other instances principally of metal, small portions of wood intervening. In either case, the facility with which the heat is propagated in the comparatively thin metallic socket, is strongly contrasted with the difficulty which it experiences in permeating the wood.

---

* A notice of the doctrine of Petit and Dulong that the capacities of all elemen- ms for heat are the same, will be deferred till I have treated of atomic pro- s.

An inferiority of conducting power, when compared with metals, is also displayed by common bone, whalebone, ivory, porcelain, and especially glass.

102. *Inequality of Conducting Power, experimentally illustrated.*



Let there be four rods, severally of metal, wood, glass, and whalebone, each cemented into a ball of sealing wax. Let each rod, at the end which is not cemented to the wax, be successively exposed to the flame excited by a blow pipe. It will be found, that the metal becomes quickly heated throughout, so as to fall off from the wax; but the wood or whalebone may be destroyed, and the glass bent by the ignition, very near to the wax, without melting it so as to liberate them.

Rationale of the Fracture of Glass or Porcelain by Heat.

The fracture of glass or porcelain, exposed to fire, is the consequence of an inferior conducting power; as the heat is not distributed with quickness enough to produce a uniform expansion. Hence glass is liable to crack by heat, in proportion as it is thinner. It may be divided by a heated iron, by a string steeped in oil of turpentine and inflamed, or by the heat generated by friction. See article 112.

Metals are by far the best conductors of caloric. There are, however, scarcely two that conduct it equally well.

Table of the Conducting Power of various Metals.

Despretz has ascertained by exact experiments, that the conducting power of the following metals is in the ratio of the subjoined numbers.

Gold,	1000.0
Silver,	973.0
Copper,	898.0
Platinum,	381.0
Iron,	374.3
Zinc,	363.0
Tin,	303.9
Lead,	179.6

Explanation of the Process by which Heat is supposed to be communicated in Solids.

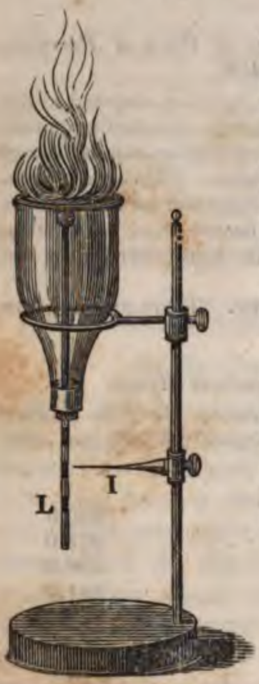
I conceive that in solids, the stratum of atoms forming the surface first exposed to the heat, combining with an excess of this principle, divides it with the next stratum. The caloric received by the second stratum, is in the next place divided between the second and third stratum. In the mean time the first stratum has received an additional supply of caloric, which passes to the second and third stratum as in the first instance; while the quantity, at first received by them, is penetrating further into the mass.

It is I trust easy to conceive that, by the process thus suggested, caloric may find its way throughout any body, for the particles of which it may have sufficient affinity. Probably the superior conducting power of metals is due in great measure to a proportionably energetic affinity for caloric.

The conjectures, which I ventured to advance respecting the mode in which caloric may exist in atmospheres about atoms, seem to be peculiarly applicable to the case of metals, on account of their great expansibility by heat, and susceptibility of contraction by cold.

If caloric be not interposed in a dense repulsive atmosphere between metallic atoms, how can its removal cause that approximation of those atoms towards each other, without which the diminution of bulk invariably consequent to refrigeration could not ensue?

103. *Liquids almost destitute of Conducting Power.*



That liquids are almost devoid of power to conduct heat, is proved by the inflammation of ether over the bulb of an air thermometer, protected only by a thin stratum of water.

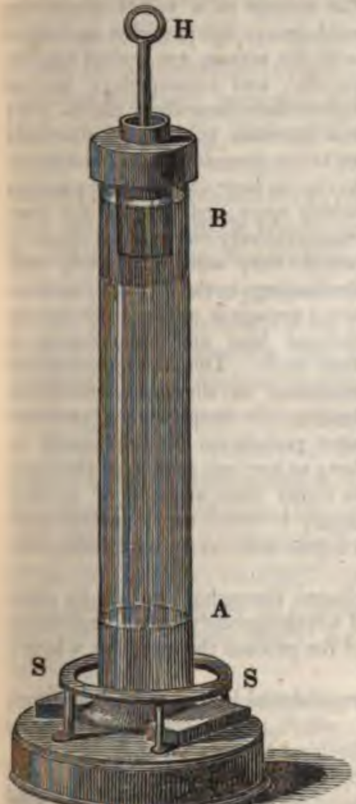
The inflammation of ether upon the surface of water, as represented in this figure, does not cause any movement in the liquid included in the bore of the air thermometer at L, although the bulb is within a quarter of an inch of the flame. Yet the thermometer may be so sensitive, that touching the bulb, while under water, with the fingers, may cause a very perceptible indication of increased temperature.

By placing the sliding index, I, directly opposite the end of the column of liquid in the stem of the thermometer, before the ether is inflamed, it may be accurately discovered whether the heat of the flame causes any movement in it.

104. *Communication of Caloric by Circulation.*

That caloric cannot be communicated in liquids, unless it be so applied as to cause a circulation of the particles, is experimentally demonstrated by the following experiment.

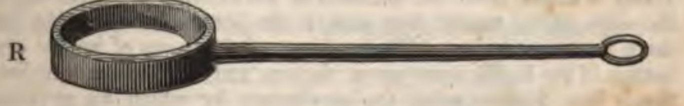
A glass jar, about 30 inches in height, is supplied with as much water as will rise in it within a few inches of the brim. By means of a tube descending to the bottom, a small quantity of blue colouring matter is introduced below the colourless water so as to form a stratum as represented at A, in the engraving. A stratum, differently coloured, is formed in the upper part of the vessel, as represented at B. A tin cap, supporting a hollow tin cylinder, closed at bottom, and about an inch less in diameter than the jar, is next placed as it is seen in the engraving, so that the cylinder may be concentric with the jar, and descend about 3 or 4 inches into the water.



The apparatus being thus prepared, if an iron heater, H, while red-hot, be placed within the tin cylinder, the coloured water, about it, soon boils; yet neither of the coloured strata intermingle with the intermediate colourless mass; and on sliding the finger upwards in contact with the glass, the heat will be found to have penetrated only a very small distance below the tin cylinder. But if the ring, R, be placed, while red-hot, upon the iron stand which surrounds the jar at S S, the portion of the liquid coloured blue, being opposite to the ring, will rise until it encounters the warmer, and of course lighter, particles, which have been in contact with the tin cylinder. Here its progress upwards is arrested; and, in consequence of the diversity of the colours, a well defined line of separation is soon visible.

The phenomena of this interesting experiment may be thus explained.

If the upper portion of a vessel, containing a fluid, be heated exclusively, the neighbouring particles of the fluid being rendered lighter by expansion are more indisposed, than before, to descend from their position. But, if the particles, forming the inferior strata of the fluid in the same vessel, be rendered warmer than those above them, their consequent expansion and diminution of specific gravity causes them to give place to particles above them, which not being as warm, are heavier. Hence heat must be applied principally to the lower part of the vessel, in order to occasion a uniform rise of temperature in a contained fluid.

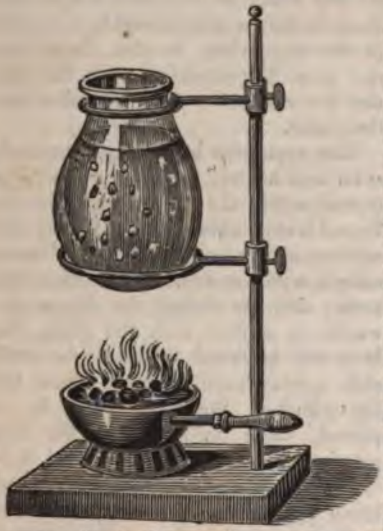


This statement is equally true, whether the fluid be aëriform or liquid, excepting that in the case of aëriform fluids, the influence of pressure on

216526

their elasticity may sometimes co-operate with, and at others oppose, the influence of temperature.*

105. *Experimental Illustration of the Process by which Caloric is distributed in a Liquid until it boils.*



On the first application of heat to the bottom of a vessel containing cold water, the particles in contact with the bottom are heated and expanded, and consequently become lighter than those above them. They rise therefore, giving an opportunity to other particles to be heated and to rise in their turn. The particles which were first heated, are soon comparatively colder than those by which they were displaced, and, descending to their primitive situation, are again made to rise by additional heat and enlargement of their bulk. Thus the temperatures reversing the situations, and the situations the temperatures, an incessant circulation is maintained, so long as any one portion of the liquid is cooler than another, or in other words, till ebullition takes place; previously to which every particle must have combined with as much caloric as it can receive, without being converted into steam.

The manner in which caloric is distributed throughout liquids by circulation, as above described, is illustrated advantageously by an experiment contrived by Rumford, who first gave to the process the attention which it deserves.

Into a glass nearly full of water, as represented by the foregoing figure, small pieces of amber are introduced, which are in specific gravity so nearly equal to water, as to be little influenced by gravitation.†

The lowermost part of the vessel being subjected to heat while thus prepared, the pieces of amber are seen rising vertically in its axis, and after they reach the surface of the liquid, moving towards the sides, where the vessel is colder from the influence of the external air. Having reached the sides of the vessel, they sink to the bottom, whence they are again made to rise as before. While one set of the pieces of amber are at the bottom of the liquid, some are at the top, and others at intermediate situations; thus demonstrating the movements by which an equalization of temperature is accomplished in liquids.

When the boiling point is almost attained, the particles being nearly of the same temperature, the circulation is retarded. Under these circumstances, the portions of liquid which are in contact with the heated surface of the boiler are converted into steam, before they can be succeeded by others; but the steam thus produced cannot rise far before it is condensed. Hence the vibration and singing sound which is at this time observed.

---

* See Appendix for Essay on the Gales experienced in the Atlantic States of North America.

† As amber is rather heavier than water, it is expedient to add some sulphate of soda, to increase the specific gravity of the liquid.

According to an observation of Gay-Lussac, water boils in metallic vessels at a temperature nearly *two and a half* degrees lower than in those of earthenware.

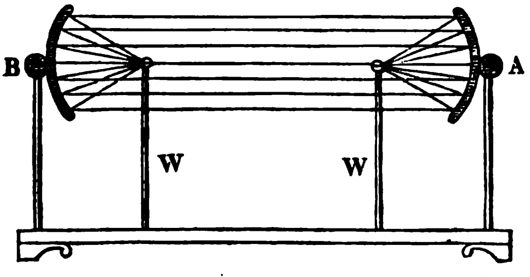
QUICK COMMUNICATION OF HEAT, OR RADIATION.

It must be evident that the heat which we receive from a fire in opposition to the draught, reaches us neither by the conducting process nor by circulation. Actual contact is evidently indispensable to the passage of heat in either of these modes. The aëriform matter which is in contact with the embers, or the blaze of a fire, forms part of a current which tends rapidly towards the flue, as must be evident from the celerity with which the sparks which accompany it are propelled. The rapidity with which the aërial particles, heated by the fire, are thus carried up the chimney, far exceeds that with which caloric can be communicated, in the opposite direction, either by the conducting process or by circulation.

The caloric received from a fire under the circumstances above mentioned, and which is analogous to that by means of which the culinary operations of toasting and roasting are accomplished, is called radiant caloric, or more usually, radiant heat. It has been called radiant, because it appears to emanate in radii or rays from every hot or even warm body, as light emanates from luminous bodies.

Radiant heat resembles light also in its susceptibility of being reflected by bright metallic surfaces; in which case it obeys the same laws as light, and is of course liable, in like manner, to be collected into a focus by concave mirrors.

106. *Model for illustrating the Operation of Concave Mirrors.*



The object of the model represented by this diagram, is to explain the mode in which two mirrors operate in collecting the rays of radiant heat emitted from one focus, and in concentrating them in another.

The caloric emitted by a heated body in the focus of the mirror, A, would pass off in radii or rays, lessening in intensity as the space into which they pass enlarges; or, in other words, as the squares of the distances. But those rays which are arrested by the mirror, are reflected from it in directions parallel to its axis.* Being thus corrected of their divergency, they may be received, without any other loss than such as arises from mechanical imperfections, by the other mirror, which should be so placed that the axis of the two mirrors may be coincident; or, in other words, so that a line drawn through their centres, from A to B, may at the same time pass through their foci, represented by the little balls supported by the wires, W W.

The second mirror, B, reflects to its focus the rays which reach it from the first; for it is the property of a mirror, duly concave, to render parallel the divergent rays received from its focus, and to cause the parallel rays which it intercepts to become convergent, so as to meet in its focus.

The strings in the model are intended to represent the paths in which the rays move, whether divergent, parallel, or convergent.

107. *Phosphorus ignited at the Distance of sixty feet by an incandescent Iron Ball.*

The opposite engraving represents the mirrors which I employ in the ignition of phosphorus and lighting a candle by an incandescent iron ball.

I have produced this result at sixty feet, and it might be always effected at that distance, were it not for the difficulty of adjusting the foci with sufficient accuracy and expedition. I once ascertained that a mercurial thermometer, when at the distance last mentioned, rose to 110 degrees of Fahrenheit.

A tallow candle is so situated, that its wick, previously imbued with phosphorus, may be in the focus of one of the mirrors. A lamp being similarly situated with respect to the other mirror, it will be easy, by receiving the focal image of the flame on any small screen, so to alter the arrangement, as to cause this image to fall upon the phosphorus. This being effected, the screen, S, placed between the mirrors, is lowered so as to intercept the rays. The iron ball being rendered white-hot is now substituted for the lamp, and the screen being lifted, the phosphorus takes fire and the candle is lighted.

Of the Diversity of Radiating Power in Metals, Wood, Charcoal, Glass, Pottery, &c.

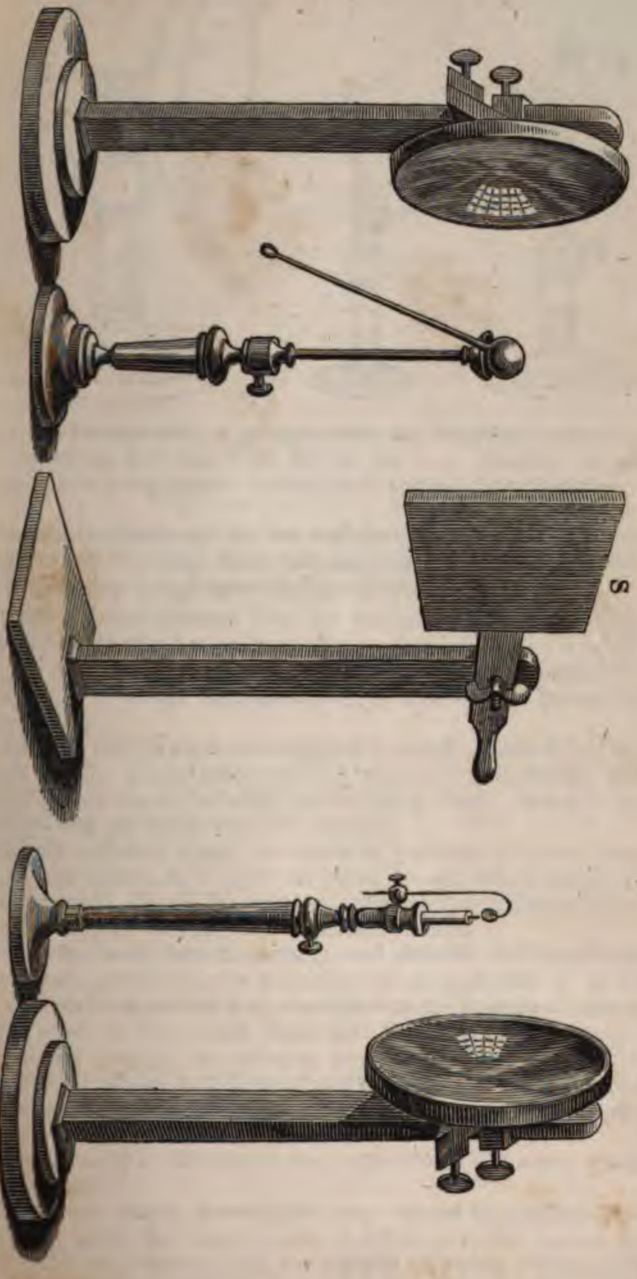
108. *Diversity of Radiating Power experimentally illustrated.*

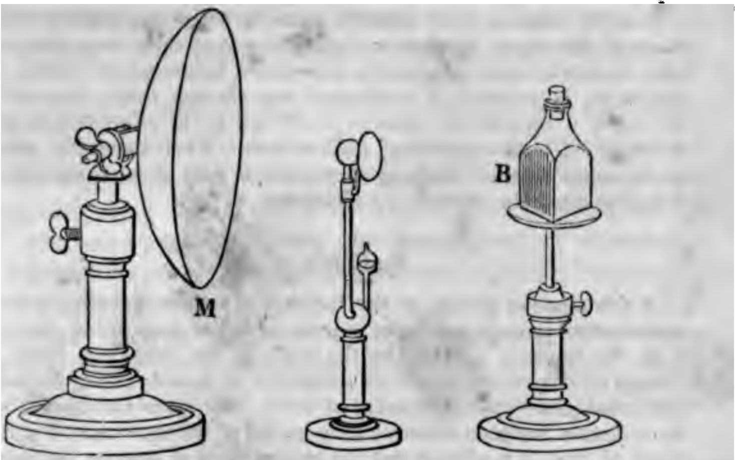
At M, (see figure, next page) a parabolic mirror is represented. At B is a square glass bottle, one side of which is covered with tin foil, and another so smoked by means of a lamp as to be covered with carbon. Between the bottle and mirror, and in the focus of the latter, there is a bulb of a differential thermometer, protected from receiving any rays directly from the bottle by a small metallic disk. The bottle being filled with boiling water, it will be found that the temperature in the focus, as indi-

---

* The axis of a mirror is in a line drawn from its centre through its focus.

Phosphorus Ignited by Radiant Heat.





cated by the thermometer, is greatest when the blackened surface is opposite to the mirror, and least when the tin foil is so situated; the effect of the naked glass being greater than the one, and less than the other.

The worst radiators are the best reflectors, and the best radiators are the worst reflectors; since the arrangement of particles which is favourable for radiation is unfavourable for reflection, and vice versa.

A polished brass andiron does not become hot when exposed from morning till night to a fire, so near that the hand placed on it is scorched intolerably in a few seconds. Fire places should be constructed of a form and materials to favour radiation: flues, of materials to favour the conducting process.

To preserve heat in air or to refrigerate in water, vessels should be made of bright metal. In the latter case, the brightness is beneficial, only because the surface cannot be bright without being clean. If soiled, its communication with the liquid would be impeded.

Rationale.—Metals appear to consist of particles so united with each other, or with caloric, as to leave no pores through which radiant caloric can be projected. Hence the only portion of any metallic mass which can yield up its rays by radiation is the external stratum.

On the other hand, from its porosity, and probably also from its not retaining caloric within its pores tenaciously as an ingredient in its composition, charcoal opposes but little obstruction to the passage of that subtile principle, when in the radiant form; and hence its particles may all be simultaneously engaged in radiating any excess of this principle with which a feeble affinity may have caused them to be transiently united, or in receiving the rays emitted by any heated body, to the emanations from which they may have been exposed.

We may account in like manner for the great radiating power of earthenware and wood.

For the same reason that calorific rays cannot be projected from the interior of a metal, they cannot enter it when projected against it from without. On the contrary, they are repelled with such force as to be reflected without any perceptible diminution of velocity. Hence the preeminence of metallic reflectors.

It would seem as if the calorific particles which are condensed between those of the metal, repel any other particles of their own nature which may radiate towards the metallic superficies, before actual contact ensues; otherwise, on account of mechanical imperfection, easily discernible with the aid of a microscope, mirrors would not be as efficacious as they are found to be in concentrating radiant heat. Their influence, in this respect, seems to result from the excellence of their general contour, and is not proportionably impaired by blemishes.

Radiation of Cold.

A thermometer placed in the focus of a mirror indicates a decline of temperature, in consequence of a mass of ice or snow being placed before it in the situation occupied by the bottle in the preceding figure. This change of temperature has been considered as demonstrating the radiation, and consequently the materiality of cold. For since the transfer of heat by radiation has been adduced as a proof of the existence of a material cause of heat, it is alleged that the transmission of cold by the same process ought to be admitted as equally good evidence of a material cause of cold.

The following is the explanation which I give of this phenomenon, agreeably to the opinion that cold is diminished heat.

I suppose that caloric exists throughout the sublunary creation, as an atmosphere held to the earth by the general attraction of all the matter in it, being in part combined with bodies in proportion to their affinities or capacities for it, and partly free. The particles of the free caloric I suppose incessantly to exert a self-repellent power, which increases with its density, as in the case of aëriform fluids. The repulsive power of caloric being in the ratio of the quantity, it follows that either a diminution or increase of temperature in any spot must equally produce a movement in the calorific particles; in the one case from the spot which sustains the change, in the other towards it.

Supposing the surface of a mirror to be subjected to the influence of a space in which a diminution of temperature has been produced, the rows of calorific particles between the mirror and the space will move into the space. The removal of one set of the calorific particles from the surface of the mirror, must make room for another set to flow into the situations thus vacated. The curvature of the surface of the mirror renders it more easy for those particles to succeed which lie in the direction of the focus.

MEANS OF PRODUCING HEAT, OR RENDERING CALORIC SENSIBLE.

Of the Solar Rays as a Source of Heat.

Of all the natural sources of heat, the sun is obviously the most prolific.

The solar rays may be collected into a focus either by the refracting influence of glasses or the reflecting power of mirrors. They may be converged by reflection, in a mode analogous to that illustrated in the case of radiant heat.

The glasses employed for concentrating light are called lenses from their shape, which is that of a double convex lens.

As the intensity of the heat produced by the solar beams is in proportion to the quantity of them which may be collected upon any given spot, there appears to be scarcely any limits to the temperature producible by their condensation, excepting our incompetency to enlarge or multiply burning glasses or mirrors, without rendering them unmanageable or inefficient.

Scarcely any occurrence of antiquity has excited more curiosity than the destruction of the Roman ships, which Archimedes is alleged to have accomplished by concentrating upon them the rays of the sun.

Buffon arranged a number of plane mirrors so as to *concur* in reflecting the solar image upon the same spot. He was by these means enabled to fuse lead at a distance of 140 feet. This contrivance resembles that which Archimedes employed, if we may judge from the accounts which have been given of the latter. Previously to the employment of pure oxygen gas, the hydro-oxygen blowpipe, and voltaic electricity, there was no known mode of rivalling the heat produced by large burning-glasses and mirrors.

Sensible Heat evolved by Electricity.

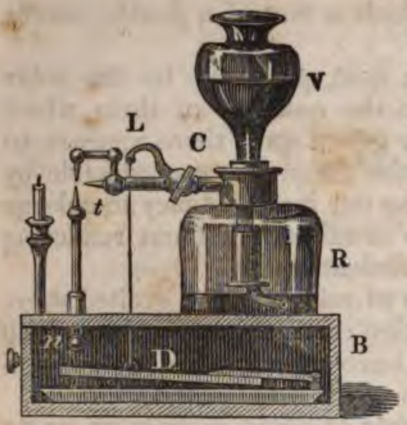
The power of lightning to produce ignition is displayed by the conflagration of ships and barns, in consequence of the ignition of cotton, hay, or other combustibles. The power of the electric spark to ignite an inflammable gaseous mixture is agreeably illustrated, by means of the apparatus described in the following article.

109. *Application of an Electrophorus to the Ignition of Hydrogen Gas, generated in a Self-Regulating Reservoir.*

In order that the interior of this apparatus may be described, (see fig. next page) the side of the box, B, below the reservoir, R, is supposed to be removed. On the bottom of the box is a square metallic dish covered by a stratum of sealing wax. The metallic plate, D, is supported behind by a glass rod, cemented to a socket soldered to a hinge. Upon this hinge, like the lid of a trunk, the plate moves freely, while connected with the lever, L, by a silken cord. The lever, L, is attached to the key of the cock, C; so that opening the cock causes the plate to rise, and touch the knob, *n*, of the insulated wire. This wire terminates just before the orifice of the tube, *t*, proceeding from the cock, and about one-eighth of an inch from another wire, supported upon that tube.

The glass reservoir, R, receives into its open neck, the tapering part of a glass vessel, V, which is so proportioned, and fitted to the neck by grinding, as to make with it an air-tight juncture.

Below this juncture, the vessel, V, converges, until it assumes the form of a tube,



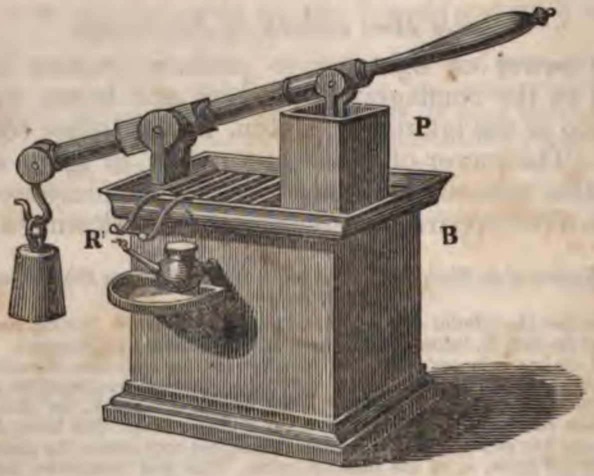
reaching nearly to the bottom of the reservoir. Around the tube thus formed a coil of zinc is supported, so as to be above the orifice of the tube, constituted as abovementioned.

If the reservoir be sufficiently supplied with diluted sulphuric acid, the reaction between this solvent and the zinc will evolve hydrogen gas. The gas thus evolved, if not allowed to escape, will force the liquid which generates it through the orifice of the tube proceeding from the vessel, V, into the cavity of this vessel, until the quantity of the acid remaining below, is insufficient to reach the zinc. Whenever this takes place, the evolution of hydrogen ceases. As soon, however, as, by opening the cock, any portion of the gas is allowed to escape, an equivalent bulk of acid descends into the reservoir, and reacts with the zinc, until, by the further generation of hydrogen, the portion of acid which may have descended shall again be expelled from the lower into the upper vessel. At the same moment that, by turning the cock. C, a jet of gas is emitted, the plate of the electrophorus being lifted against the knob *n*, of the wire, an electrical spark will pass from the other end of this wire to that of the wire supported by the cock, and of course uninsulated by its communication with the operator's hand. Consequently the jet of hydrogen will be ignited, and will light a candle exposed to its influence.

For a rationale of the electrophorus, as also for other exemplifications of the igniting power of electric discharges, I refer to the section on electricity, articles 44, 45, 46, and 50.

110. *Ignition by Galvanism.*

Galvanic Apparatus for Lighting a Lamp.

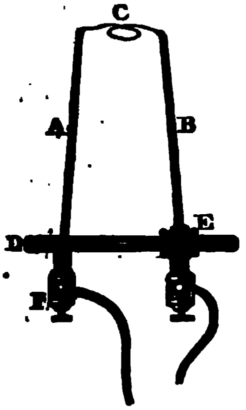


The preceding figure represents an instrument for lighting a lamp by means of a galvanic discharge from a calorimotor; for an explanation of which I must refer the reader to my lectures on galvanism.

The plunger, P, being depressed by means of the handle attached to it, some acid contained in the box, B, is displaced, so as to rise among the galvanic plates. By the consequent evolution of the galvanic fluid, a platinum wire, fastened between the brass rods forming the poles of the calorimotor, and projecting over the lamp as seen at R, is rendered white hot, and a filament of the wick, previously laid upon it, is inflamed.

The weight acts as a counterpoise to the plunger, and when it is not depressed by the hand, keeps it out of the acid.

111. *Galvano-ignition Apparatus.*



In many of my experiments, for the purpose of producing the temperature of combustion in cavities inaccessible by ordinary means, I employ a wire ignited by being made a part of a galvanic circuit.

Of the apparatus by which this object is effected, I shall here give a description accompanied by a figure, which will convey a general idea of the contrivance, applicable to all cases where it may be used. Having thus prepared the student, I shall in future refer to it under the name at the head of this article, in order to avoid circumlocution, and unnecessary recurrence to analogous description. D represents a section of a metallic disk.. A, B, two metallic rods, which should be of iron, if in contact with mercury, but which otherwise may be of brass, are made to enter the cavity. If, as in general, the rods pass through a metallic plate or cylinder, one of them may be soldered to the plate or cylinder. The other must be so secured, where it passes through the metal, by a collar of leather, E, as to insulate it from all metallic contact, and to render the aperture through which it enters, air-tight if necessary. The rods may extend into the cavity to any convenient distance, their terminations being approximated, more or less, as may be desirable, but not brought in contact. To one of these rods, where it terminates within the cavity, one end of a fine platinum wire is soldered; the other end of the wire being soldered in like manner to the similarly situated termination of the other rod. To the rod secured by the collar of leather, at the termination on the outside of the cavity, a gallows screw is attached, by means of which a flexible lead or copper rod may be made fast at one end, while the other is fastened to one of the poles of a competent calorimotor. To the other pole of the calorimotor, another rod is attached at one end, which at the other may be secured by a gallows screw, either soldered to the plate, or to the projecting extremity of the uninsulated rod, as in the figure. Sometimes the last mentioned rod is left at liberty, so as to be made to touch, when desirable, any part of the apparatus having a metallic communication with the uninsulated rod. If, under these circumstances, the calorimotor be put in operation, the wire will be ignited.

Ignition by Collision.

The ignition of spunk, tinder, or gunpowder, by means of flint and steel, comes under this head. In the rotary match box, the collision is produced by a wheel thrown into rapid rotation. An analogous apparatus, called a steel mill, had long been employed to procure light in mines infested with light carburetted hydrogen, prior to Sir H. Davy's invention of the safety lamp. This gas explodes on coming into contact with the flame of a lamp or candle, but is not ignited by the scintillations from a steel mill.

Heat produced by Percussion.

A rod of iron hammered with great rapidity by a skilful workman, will become so hot as to ignite a sulphur match, and phosphorus may, in this way, be easily ignited; but the same piece of iron cannot be ignited by percussion more than once.

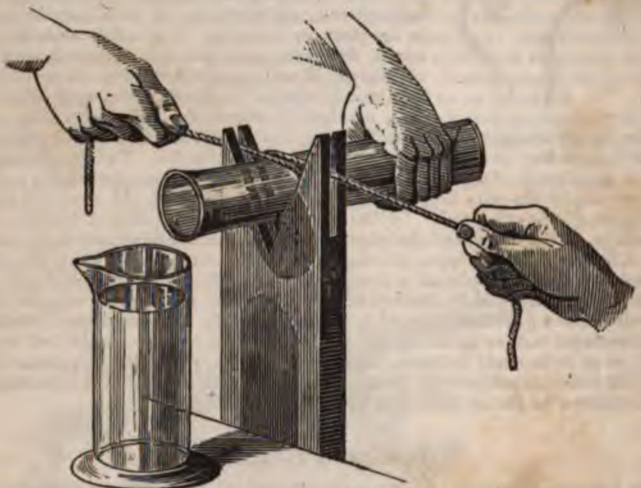
Coins grow hot when struck in the coining press, but, if repeatedly struck and cooled during each interval, are less heated at each suc blow. At the same time the density of the mass is permanently increased, probably by the expulsion of the caloric, interposed between the metallic atoms. See rationale of the conducting process, page 97.

Heat produced by Friction.

Friction, as a means of producing heat, differs from percussion; since in the case of friction, the effect being confined to the surfaces of bodies, there is no condensation of the mass subjected to the process. Collision differs both from percussion and friction; for it produces ignition only in the minute portions of matter which are struck off. The masses employed are not heated.

It is well known that savages avail themselves of the friction of wood to generate fire. Wood revolving in the lathe may be carbonized, throughout the circle of contact, by holding against it another piece properly sharpened. By rubbing one cork against another, sufficient heat is produced to ignite phosphorus.

112. *Glass so heated by the Friction of a Cord, as to separate into two parts on being subjected to Cold Water.*



The process for dividing a tube, which I am about to describe, illustrates at once the heat produced by friction, and the non-conducting power of glass.

Some years ago, Mr. Isaiah Lukens showed me that a small phial or tube might be separated into two parts, if subjected to cold water, after having been heated by the friction of a cord made to circulate about it, by two persons alternately pulling in opposite directions. I was subsequently enabled to employ this process for dividing large vessels of four or five inches in diameter; and likewise to render it in every case more easy and certain, by means of a piece of plank forked like a boot-jack, as represented in the preceding figure, and also having a kerf or slit cut by a saw, parallel to, and nearly equidistant from, the principal surfaces of the plank, and at right angles to the incisions forming the fork.

By means of the fork, the glass is easily held steady by the hand of one operator. By means of the kerf, the string, while circulating about the glass, is confined to the part where the separation is desired. As soon as the cord smokes, the glass is plunged into water, or if too large to be easily immersed, the water must be thrown upon it. This method is always preferable when the glass vessel is so open, that, on being immersed, the water can reach the inner surface. As plunging is the most effectual method of employing the water, I usually, in the case of a tube, close the end which is to be sunk in the water, so as to restrict the refrigeration to the outside.

Rationale.—If the friction be continued long enough, the glass, though a very bad conductor of heat, becomes heated throughout in the part about which the friction takes place; of course it is there expanded. While in this state, being suddenly refrigerated by the cold water on the outside only, the stratum of particles immediately affected contracts, while that on the inside, not being chilled, undergoes no concomitant change. Hence a separation usually follows.

Ignition by Attrition.

If, whilst a thin disk of sheet iron is made to revolve rapidly upon its axis by means of a lathe, the circumference be brought into contact with a plate of steel, heat will be so copiously evolved at the place of collision, that the steel may be actually divided by the successive ignition and abrasion of a portion of its particles. The ignition is confined to the steel, because the heat, evolved in this case, is too much divided upon the whole circumference of the iron, to affect any part materially; whereas, a few particles of steel having to encounter successively many of iron, the heat, generated by the attrition, accumulates in the former, so as to produce visible ignition.

This case differs from that of pure collision, since, although heat is produced in the abraded particles, it is also produced in the mass; and it differs from that of friction, since, although one of the masses is heated, the greatest heat is evolved in the matter which is abraded.

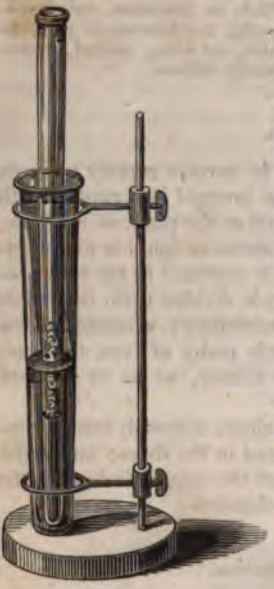
Heat produced by Combination.

The union of tin or lead with platinum is productive of a remarkable elevation of temperature. For the exhibition of this phenomenon, both metals must be in the state of foil, and the more fusible metal rolled up in the platinum, so as to form a scroll as large as can be conveniently ignited by means of the blowpipe. As soon as the scroll reaches a red heat, it becomes instantaneously incandescent, the union being effected with an astonishing energy.

113. *Experimental Illustration.*

Tin foil and platinum foil are rolled up into a scroll, the tin being innermost, and the whole subjected to the flame of the hydro-oxygen blowpipe. Almost as soon as the mass reddens, it becomes incandescent with an energy almost explosive.

114. *Boiling Heat produced in Alcohol, by the Mixture of Sulphuric Acid with Water.*



The evolution of caloric, produced by the mixture of liquids, has long been an object of attention among chemists. A sensible increase of temperature arises from the mixture of alcohol with water. The same consequence ensues, to a much greater extent, from mixing water with sulphuric acid. The heat, thus generated, may be conveniently displayed by means of the apparatus represented by the adjoining figure.

Into the inner tube introduce as much alcohol, coloured to render it more discernible, as will occupy it to the height of three or four inches. Next pour water into the outer tube, till it reaches about one-third as high as the liquid contained in the inner tube; and afterwards add to the water about three times its bulk of concentrated sulphuric acid. The liquid in the inner tube will soon boil violently, so as to rise in a foam.

Solution the Means of producing Heat or Cold.

Solution produces either heat or cold, according to the nature of the substance dissolved and of the solvent employed.

Nitric acid grows warm while dissolving silver or copper, and is still more heated during its reaction with tin. Water becomes cold in dissolving nitre, and still colder in dissolving nitrate of ammonia. Sulphuric acid becomes at first boiling hot, and afterwards freezing cold, by successive additions of snow.

Heat produced by Mechanical Action inducing Chemical Decomposition.

With the view of showing the necessity of distinguishing heat as a latent cause from sensible heat, the explosion of a fulminating powder by percussion was exhibited. This phenomenon falls under the definition given at the head of this article. Ignition produced in this way has of late been advantageously applied to fire arms and fowling pieces.

It seems probable that the mechanical force of the blow causes some particles of the compound to be nearer to each other; in consequence of which an arrangement of the elements ensues, inconsistent with the retention of the large quantity of caloric with which they were previously combined.

Heat produced by Condensation experimentally illustrated.

Spunk or tinder may be ignited, if introduced into a condenser of appropriate construction, and the air forcibly condensed upon it.

It has already been shown that, during its rarefaction, air becomes cooler, while during its condensation it becomes warmer. It seems that when the compression is carried very far, so much caloric is liberated as to cause ignition. This result is attained by means of a small condenser, the construction of which does not differ from that which has been described (82), excepting that a cock for the introduction of the spunk is substituted for the valves. The ignition is accomplished by having the piston so situated, as that there may be as much air as possible included by it, and then driving it home, with a jerk, so as to condense the air upon the matter to be ignited with great force and rapidity. Sometimes the instrument is made of glass without a cock, so that the ignition may be seen; the spunk being inserted into a cavity in the end of the piston, which must of course be withdrawn as soon as the ignition is effected, in order to make any useful application of the ignited spunk.

It appears evidently from this phenomenon that, in air, when the temperature is uniform, the quantity of caloric in proportion to the ponderable matter lessens as the density increases.

This inference would appear, at first view, irreconcilable with those experiments which demonstrate that, in steam, the quantity of caloric is always directly as the weight of water; but the discordancy disappears when we consider that the heat of the condensed air is estimated after the escape of the sensible heat liberated by the compression; while in the case of steam this cannot be permitted, as a loss of sensible heat would be attended with a partial condensation, producing a proportionate diminution of density.

If steam, formed at the boiling point of 212° and having no access to water in the liquid form, were to be raised to some higher temperature, 500° for instance, it might be subjected to compression without being partially liquefied; so that the same law would apply to it as to atmospheric air, which always exists at a heat far above its boiling point, and has no access to any of its own kind of ponderable matter in the liquid form.

By the boiling point of air, I mean that temperature below which it would become liquid. We have, I think, reason to infer that all aëriform fluids would prove susceptible of liquefaction, if our power of abstracting caloric or producing cold were unlimited.

115. *Experimental Illustration.*

Spunk ignited in consequence of the compression of air, by means of an appropriate condenser.

Of Fermentation as a Source of Heat.

It is well known that vegetable substances, while undergoing fermentation, acquire a great accession of heat; and that green hay is at times spontaneously ignited. The heat generated in stable litter is employed to sustain the temperature necessary to the corrosion of the metal in the manufacture of white lead.

Of Vitality as a Source of Heat.

The temperature of warm blooded animals demonstrates the power of animal life to evolve caloric.

In no other respect is chemical reaction so analogous to that which ta place within the domain of vitality, as in their common association heat, both as cause and effect. The old chemical law that bodies do act unless fluid, to which the actual exceptions are but few, shows much the processes of chemistry are dependent on the principle, wit which there could be no fluidity. The dependency of life on tempera is self evident. Seeds and eggs lie dormant until excited by a due de of heat.

Of the Means of exciting or supporting Heat for the Purposes o Chemistry.

It is well known that the activity of fire is dependent on the suppl air, as well as on the quantity and quality of the fuel.

As the air which comes into contact with a fire is necessarily m rarefied by the expansive power of heat, it has consequently a tende to ascend in a vertical current, giving place to the colder and heavier in the vicinity, agreeably to the principles already illustrated. See and 105.

The limits of this vertical current of heated air, in the case of a sm lamp flame, are well indicated by the fuliginous particles. It may, h ever, be observed that the influx of the cold air takes place not only level with the flame where it must quicken the combustion, but also a the flame, where it narrows the heated column and retards its progr In the Argand lamp, a glass chimney defends the vertical current lateral pressure, until it has attained a sufficient height to cause an quate current of air to act upon the flame.

In conformity with the principle thus illustrated by this elegant useful contrivance, all air furnaces are constructed. The hot air and pour proceeding from the fire, being received into a flue, or the furn being tall enough of itself to protect the ascending current, all the which flows in to take its place is made to pass through the fuel.

It would not be expedient to take up the time of the student with a tailed explanation of the various furnaces used by chemists. Some them will be introduced in subsequent illustrations, as associated processes, in which their utility and the method of using them will evident.

116. *Experimental Illustration.*

An Argand lamp shown and explained. Also an gand lamp with concentric wicks.

Of the Bellows, and of Forge Fires.

The bellows is so universally known as the means of exciting com tion employed by smiths, as to render it scarcely necessary to men the forge fire as among the most efficient and convenient methods of ducing heat for the purposes of chemistry. The supply of air is, in case, yielded by an operation analogous to that of the condenser.

In the double bellows, the additional compartment performs a part, equalizing the efflux, equivalent to that of the air vessel in the case of forcing pump, the valves operating in the same way.

117. *Lamp without Flame.*

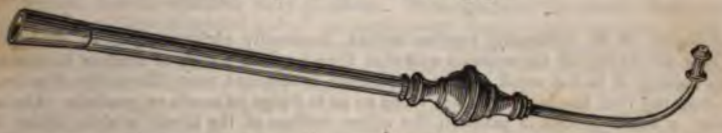
About the wick of a spirit lamp, a fine wire of platinum is coiled, so as to leave a spiral interstice between the spiral formed by the wire; a few turns of which should rise above the wick.

If after lighting a lamp thus constructed, the flame be extinguished by a gentle blast, or the transient application of an extinguisher, the wire will be found to remain red hot; as it retains sufficient heat to support the combustion of the alcoholic vapour, although the temperature is inadequate to constitute or produce inflammation.

Rationale.—The metallic coil appears to serve as a reservoir for the caloric, and gives to the combustion a stability, of which it would otherwise be deficient.

There is some analogy between the operation of the wire in acting as a reservoir of heat in this chemical process, and that of a fly wheel as a reservoir of momentum in equalizing the motion of machinery.

118. *Of the Mouth Blowpipe.*



As a fire is quickened by a blast from a bellows, so a flame may be excited by a stream of air propelled through it from the blowpipe.

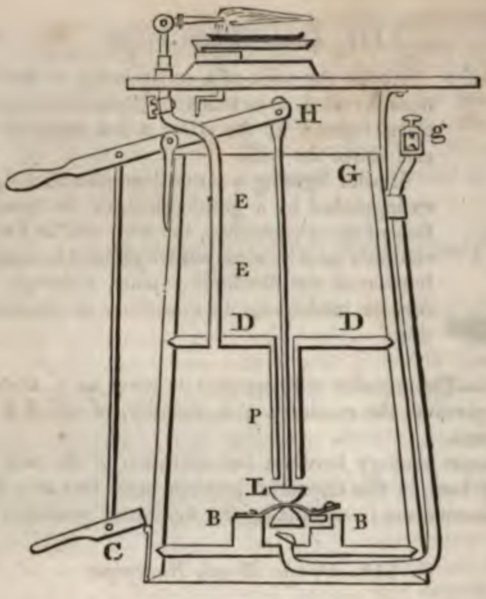
The instrument known by this name, is here represented in one of its best forms. It is susceptible of various other constructions; all that is essential being a pipe of a size at one end suitable to be received into the mouth, and towards the other end having a bend nearly rectangular, beyond which the bore converges to a perforation, rather too small for the admission of a common pin. There is usually, however, an enlargement, as represented in this figure, to collect the condensed moisture of the breath.

The mouth blowpipe is of great service in assaying minute portions of matter, so as to form a general idea of their nature.

The celebrated Berzelius, who has written an octavo volume on the subject of this instrument, informs us that by means of it Gahn discovered tin in a mineral, in which it had not been detected by analysis, although existing only in the proportion of one per cent: also that he had often seen him extract a globule of metallic copper from the ashes of a quarter of a sheet of paper. The utility of the mouth blowpipe will be manifested in several future illustrations.

119. *Engraving and Description of the Hydrostatic Blowpipe.*

The *hydrostatic blowpipe*, consists of a cask, divided by a horizontal partition, D D, into two apartments. From the upper apartment, a pipe of about three inches in diameter, (its axis coincident with that of the cask,) descends, until within about six inches of the bottom. On the bottom is fastened, by screws, a hollow cylinder



of wood, B B, externally twelve inches, internally eight inches, in diameter.* Over the cavity of the wooden cylinder thus formed, a disk of leather is fastened by nailing it to the wood, as the parchment is fastened over the cavity of a drum, excepting that the leather is left loose so as to bulge as much as possible. On one side, a small groove is made in the upper surface of the block, which, when the leather is nailed on each side of it, constitutes a lateral air-tight passage. This lateral passage communicates with a hole bored vertically into the wood by a centre-bit; and a small strip of the leather being extended so as to cover this hole, is made, with the addition of some disks of metal, to constitute a valve, opening upwards. In the bottom of the cask, there is another valve opening upwards. A piston rod, passing perpendicularly through the pipe, P, from the handle H, is fastened near its lower end to a hemispherical mass of lead, L. The portion of the rod beyond this proceeds through the centre of the leather, which covers the cavity formed by the hollow cylinder; also through another mass of lead, like the first, which being forced up by a screw and nut, subjects the leather, between it and the upper leaden hemisphere, to a pressure sufficient to render the juncture air-tight. From the partition, D D, an eduction pipe is carried under the table, where it is fastened, by means of a screw, to a cock which carries a blowpipe so attached by a small swivel joint, as to be adjusted in any direction which may be necessary. A suction pipe passes from the opening covered by the lower valve, under the bottom of the cask, and rises vertically, close to it, on the outside, terminating in a gallows, *g*, for the attachment of any flexible tube which may be necessary.

The apparatus being thus arranged, and the cask supplied with water, until the partition is covered, to the depth of about two inches; if the piston be lifted, the leather will be bulged up, and will remove, in some degree, the atmospheric pressure from the cavity beneath it; consequently, the air must enter through the lower valve, to restore the equilibrium. When the piston is depressed, the leather being bulged in the opposite direction, the cavity beneath it is diminished, and the air, being compressed, forces its way through the lateral valve into the lower apartment of the cask. This apartment being previously full of water, a portion of this fluid is pressed up, through the pipe, into the upper apartment. The same result ensues every time that the stroke is repeated; so that the lower apartment soon becomes replete with air, which is retained by the cock, until its discharge by the blowpipe is requisite.

---

* It should be stated that the leather air pump, B B, is not correctly represented as respects its dimensions, which ought to be in diameter as large nearly as the space will admit. The cavity in the block, under the leather, ought to be nine inches in width.

The cock being opened, the air confined in the lower apartment, is expelled by the pressure of the water in the upper apartment, which, as the air which had displaced it escapes, descends and reoccupies its former situation. The piston is worked either by the handle, or the treadle at C.

In order to supply the cask with oxygen gas, it is only necessary to attach to the suction pipe, (by means of the gallows and screw at *g*,) another pipe, duly flexible, and terminating within a bell containing the gas in question, over the pneumatic cistern: or the pipe may communicate with a leather bag filled with oxygen. I have one which will hold fifty gallons. The seams are closed by rivets, agreeably to Pennock and Sellers's plan for mail bags and fire-hose.

Of the Enameller's Lamp.

On the table of the hydrostatic blowpipe, a lamp is represented, which I use in blowing the bulbs of thermometers. This is a modification of the "enameller's lamp," so called, because such lamps have been used in a certain species of enamelling.

It is essential to the enameller's lamp, that the flame be excited by a jet of air. Usually, a small double bellows is placed under the table so as to be worked by the foot, causing a jet of air to act upon the flame through a pipe terminating in a beak like that of a blowpipe.

Of the Hydro-Oxygen or Compound Blowpipe.

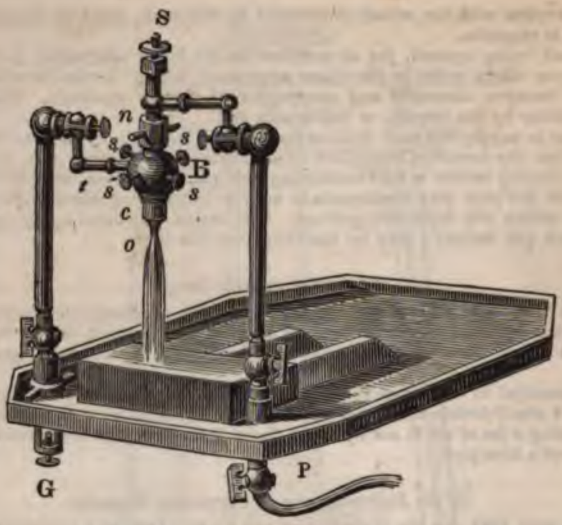
In the year 1801, by the invention of the hydro-oxygen or compound blowpipe, of which I published an account the following year, I was enabled to fuse several of the pure earths which had previously been deemed infusible; and likewise not only to fuse, but to volatilize pure platinum. Subsequently, my friend Professor Silliman, by a more extended use of the instrument, fused a great number of substances insusceptible of fusion by the common blowpipe. My memoir was republished in London, in Tilloch's Magazine; also at Paris, in the Annales de Chimie, and was noticed by Murray in his treatise of chemistry, and by Dr. Hope, in his lectures: yet, when a modification of the hydro-oxygen blowpipe was contrived by Mr. Brooke, Dr. Clarke, by means of this modification, repeated my experiments and those of Professor Silliman, without any other notice of our pretensions than such as were calculated to convey erroneous impressions. For an exposure of the injustice of this procedure, I refer to some "Strictures on Clarke's Gas Blowpipe," which will be found in the Appendix.

Much has been said in some of the British newspapers, of the application in light-houses, of the light reflected by lime, when subjected to the flame of the compound blowpipe. This is treated as a new invention, although in my original Memoir, published more than twenty years before, I spoke of the light so created as intolerable to the naked eye. A similar observation will be found in the description given by my friend, Professor Silliman, of the phenomenon in question. It follows that the English operator can only lay claim to a new application of a previous discovery.

120. *Engraving and Description of an improved Compound Blowpipe and its Appendages.*

The following figure represents a compound blowpipe which I contrived and executed myself in the year 1813; but, fearing it might be deemed unnecessarily complex, I did not then publish an account of it. Experience has shown that the complication of its structure does not render it more difficult to use than the simplest instruments intended for the same purpose; while its parts are peculiarly susceptible of advantageous adjustment.

B is a brass ball, with a vertical perforation, terminating in a male screw above, and in a female screw below. Another perforation, at right angles to this, causes a communication with the tube, *t*, which enters the ball at right angles. A similar but smaller brass ball may be observed above, with perforations similar to those in the larger ball, and a tube, in like manner, entering it laterally. This ball terminates in a male screw below as well as above. The thread of the lower screw is curved to the left, while that of the screw of the larger ball, which enters the same nut, *n*, is curved to the right. Hence the same motion causes the male screws to approach, or recede from each other, and thus determines the degree of compression given to a cork which is placed between them in the nut. At S, above the



ball, a small screw may be observed, with a milled head. This is connected with a small tube which passes through the cork in the nut, and reaches nearly to the external orifice, *o*, from which the flame is represented as proceeding. This tube is for the most part of brass, but at its lower end terminates in a tube of platinum. It communicates by lateral apertures with the cavity of the upper ball, but is prevented by the cork from communicating with the cavity in the other ball. Hence it receives any gas which may be delivered into the upper ball from the lateral pipe which enters that ball, but receives none of the gas which may enter the lower ball, B.

Into the female screw of the latter, a perforated cylinder of brass, *c*, with a corresponding male screw, is fitted. The perforation in this cylinder forms a continuation of that in the ball, but narrows below, and ends in a small hollow cylinder of platinum, which forms the external orifice of the blowpipe, *o*.

The screws, *s s s s*, are to keep, in the axis of the larger ball, the tube which passes through it from the cavity of the smaller ball. The intermediate nut, by compressing about the tube the cork which surrounds it, prevents any communication between the cavities in the two balls. By the screw, S, in the vertex, the orifice of the central tube may be adjusted to a proper distance from the external orifice. Three different cylinders, and as many central tubes with platinum orifices of different calibres, were provided, so that the flame might be varied in size, agreeably to the object in view.

I have always deemed it best to transmit the oxygen gas through the tube in the axis, since two volumes of the hydrogen being required for one volume of oxygen, the larger tube ought to be used for the former; and the jet of hydrogen is placed between a jet of oxygen within it, and the atmospheric air without.

Under the table is a gallows, G, with a screw for attaching a pipe, leading from a self-regulating reservoir of hydrogen.

In order to put this apparatus into operation, it is placed over the cask of the hydrostatic blowpipe, as it appears in the figure which has been given of that apparatus. The pipe, P, is the eduction pipe, which forms a part of that figure.

Another pipe, proceeding from a reservoir of hydrogen gas, is attached, by means of the screw and gallows, G, to one of the tubes communicating with the blowpipe.

By the operation of the bellows, the cavity of the hydrostatic blowpipe may be supplied, either with oxygen gas, or atmospheric air. In either case, in order to have the instrument in full operation, it is only necessary to open the cocks, and inflame the hydrogen.

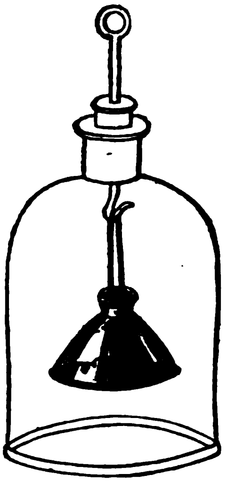
The heat produced, in this way, by the combustion of hydrogen with atmospheric air, is sufficient to fuse platinum; and when oxygen gas is employed, that metal, or any other, may be volatilized. The facility with which the hydro-oxygen flame, whether excited by pure oxygen or common air merely, may be made to act, in any convenient direction, renders it peculiarly serviceable in many operations. Its superior cleanliness is a great recommendation.

MEANS OF PRODUCING COLD, OR RENDERING CALORIC LATENT.

Cold by Vaporization.

The cold produced by evaporation has been illustrated by an experiment in which a jet of ether, co-operating with a blast, was productive of the congelation of water.* Pure prussic acid will enable me hereafter to exhibit a phenomenon still more surprising; I mean that of the freezing of one portion of a liquid, by the vaporization of another portion. I shall now proceed to show that the freezing of water may be caused by the ebullition of ether.

121. *Water frozen by Boiling Ether.*



Let a portion of water, just adequate to cover the bottom, be introduced into the vessel represented in the annexed engraving, as suspended within a receiver. Over the water let ether be added, in quantity sufficient to form a stratum from an eighth to a quarter of an inch in depth. If, under these circumstances, the receiver be placed on the air-pump plate, and sufficiently exhausted, the water freezes, while the ether boils.

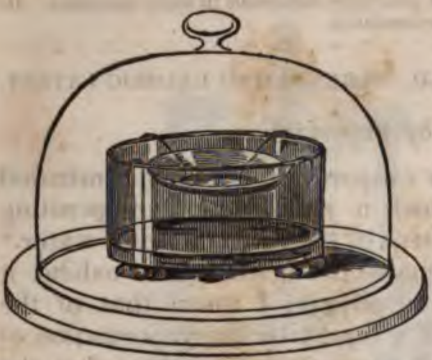
Rationale.—The freezing of the water in contact with the boiling ether, is in consequence of that increased capacity to combine with caloric already explained in article 88. Under these circumstances, the boiling point of the ether is depressed below the freezing point of water; and consequently it causes the congelation of that liquid from the same cause, that melted tin or lead will congeal under boiling water.

122. *Congelation of Water in an exhausted Receiver by the aid of Sulphuric Acid.*

In the preceding experiment, water is frozen by the rapid abstraction of caloric, consequent to the copious vaporization of ether when unrestrained by atmospheric pressure. In vacuo, water undergoes a vaporization, analogous to that of the ether in the preceding experiment; but the aqueous vapour evolved in this case is so rare, that it cannot act against the air-pump valves with sufficient force, to allow of its being pumped out of a receiver with the rapidity requisite to produce congelation. However, by

---

* See page 92.



the process which I am about to describe, water may be frozen by its own vaporization.

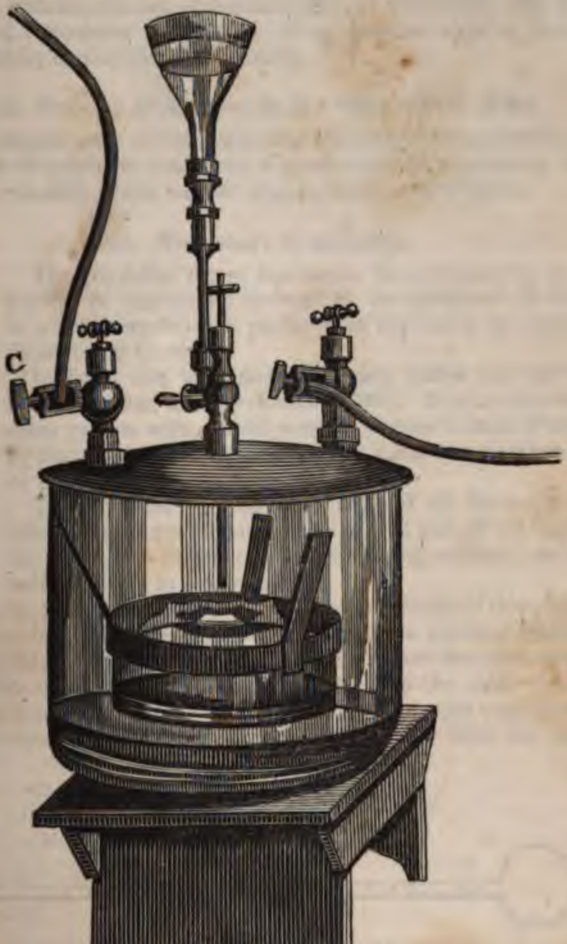
A thin dish, or pane of glass, covered by a small quantity of water, and situated over some concentrated sulphuric acid in a broad vessel, is placed within a receiver, on the air-pump plate, as represented in the annexed engraving. Under these circumstances, the exhaustion of the receiver causes the congelation of the water.

Rationale.—So long as there is no diminution of the thin aqueous vapour which, in the absence of the air, occupies the cavity of the receiver, the elastic reaction of that vapour prevents the production of more vapour; but when, as in the case in point, the vapour is largely in contact with sulphuric acid and consequently rapidly absorbed, a corresponding vaporization of the water takes place to supply the deficiency thus created. The caloric requisite for the generation of the vapour thus formed is taken from the residual liquid which finally freezes in consequence.

123. *Improved Apparatus for freezing Water by the aid of Sulphuric Acid.*

Finding the experiment, for which the apparatus represented by the preceding figure is usually employed, liable to fail from the imperfection of cocks, dependent for their efficacy on a metallic joint, I contrived the apparatus which the opposite engraving is intended to represent, and which I shall proceed to describe. A brass cover is so well fitted to the rim of a large glass jar as to be quite air-tight. In operating, the bottom of the jar was covered with sulphuric acid, and another jar with feet, also supplied with acid enough to make a stratum half an inch deep on the bottom, is introduced as represented. The bottom of the vessel last mentioned, is, by means of the feet, kept at such a height above the surface of the acid in the outer jar, as not to touch it. Upon the surface of the glass vessel, a small piece of very thin sheet brass is placed, made concave in the middle, so as to hold a small quantity of water. The brass cover is furnished with three valve cocks, one communicating with the air pump, another with a barometer gauge, and the third with a funnel supplied with water.

With the apparatus thus arranged, having made a vacuum on a Saturday, I was enabled to freeze water situated on the brass, and to keep up the congelation till the Thursday following. As water in the state of ice evaporates probably as fast as when liquid, the whole quantity frozen would have entirely disappeared during the night, but for the assistance of a watchman whom I engaged to supply water at intervals. At a maximum I suppose the mass of ice was at times about two inches square, and from a quarter to a half an inch thick. The gradual introduction of the water, by aid of the funnel and valve cock, and of the pipe represented in the figure, by which it was conducted to the cavity in the sheet brass, enabled me to accumulate a much larger mass than I could have otherwise procured. The brass band which embraces the inner jar near the brim, *Apparatus for the Congelation of Water in Vacuo, by means of Sulphuric Acid.*



with the three straps proceeding from it, serves to keep this jar in a proper position; that is, concentric with the outer jar.

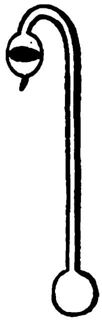
In this experiment, I employed an air-pump upon a new construction, which I have lately contrived, and of which a description will be given in the Appendix.

Congelation, as effected in the experiments above described, may be accomplished by the aid of any substance having a very strong affinity for water, as for instance chloride of calcium, clay, or whinstone, after having been rendered anhydrous by ignition. Even parched meal or flour has been successfully employed in the process.

Of the Freezing of Mercury by the Vaporization of Ice.

If a pear-shaped mass of ice containing the metal be suspended over a large surface of sulphuric acid, and a good exhaustion obtained, it will freeze the quicksilver which may be kept solid for several hours.

124. *Wollaston's Cryophorus.*



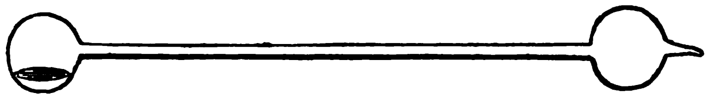
The adjoining figure represents the cryophorus, or frost bearer, an instrument invented by the celebrated Wollaston, in which congelation is produced in one cavity by rapid condensation in another.

In form, this instrument obviously differs but little from the palm glass, already described (96). It is supplied by the same process with a small portion of water instead of alcohol; so that there is nothing included in it but water, either liquid or in vapour.

The cryophorus being thus made, if all the water be allowed to run into the bulb near the bent part of the tube, and the other bulb be immersed in a freezing mixture, the water will be frozen in a few minutes.

Rationale.—There is no difference between the causes of this phenomenon and those by which the congelation of water in vacuo is effected by the aid of sulphuric acid; excepting that in the one case the aqueous vapour is absorbed by the acid, in the other condensed by the cold. In either instance it is rapidly removed, and a proportionably rapid vaporization of the water ensues, abstracting the caloric of fluidity from the residual portion.

125. *Large Cryophorus.*

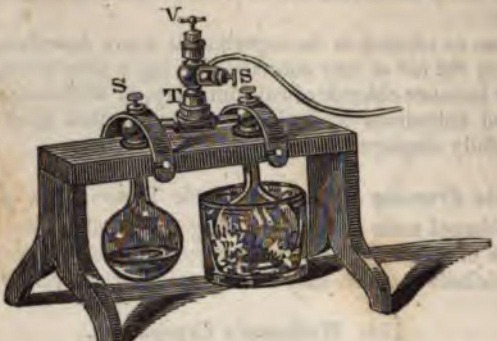


This figure represents a very large cryophorus, the blowing of which I superintended, and by means of which I have successfully repeated Wollaston's experiment.

This instrument is about four feet long, and its bulbs are about five inches in diameter.

126. *Improved Cryophorus.*

Two flasks, of which the necks have flanged orifices, are so secured in a wooden frame that, by the pressure of screws, S S, and gum elastic disks, the orifices of a tube are made to form with them severally, air-tight junctures. The orifices of the tube are furnished with brass flanges, which correspond with those terminating the necks of the flasks.



Midway between the junctures a female screw is soldered to the tube for the insertion of a valve cock V, by means of which, and a flexible tube extending to an air-pump, the flasks may be exhausted, and then closed. A small quantity of water having been previously introduced into one of them, if, while the exhaustion is sustained, the other flask be refrigerated by ice and salt, the water will be frozen.

This apparatus may be applied to the purpose of desiccation, by placing the article to be dried in one receptacle, and quicklime, chloride of calcium, or concentrated sulphuric acid in the other. The orifice of the receptacles may be made larger without inconvenience. Two large cylinders, for instance, may be used.

Chemical Combination as a Cause of Cold.

Chemical union, although more frequently the cause of increased temperature, is in many instances productive of the opposite effect.

There are few instances of chemical union which are not accompanied by a change of capacity. Of the cause of such changes we are utterly ignorant, and of course have no more reason to wonder when, by an absorption of caloric, cold is the consequence of chemical reaction, than when, by an evolution of caloric, heat arises from the same source.

In the case of the solution of snow in concentrated sulphuric acid, already adduced, we find these opposite effects resulting apparently from the same cause. Under the same head of solution, as a cause of heat or cold, it was mentioned that nitre and nitrate of ammonia produce cold during their solution. This is equally true in the case of many other salts. But the most efficient means of producing artificial cold is the solution of ice, in consequence of the reaction between it and the more deliquescent salts or the mineral acids.

It may be inferred from the statements already made, that the temperature of freezing water or melting ice is 32°; and that when ice is surrounded by other bodies at a higher temperature, it will continue to abstract from them the caloric necessary to its liquefaction, until it is all melted. It must be evident that the minimum temperature which can be thus attained is 32°. But by mingling ice in a divided state, with certain salts or acids, having a great affinity for water, and which form with it compounds of which the freezing point is lower that 32°, the mass will abstract caloric from adjoining bodies in a mode quite analogous to that in which ice has been stated to operate; while the minimum temperature attainable is as much lower as the freezing point is lower. Thus the freezing point of salt and snow is about zero of Fahrenheit's scale; consequently on mingling salt with snow, the liquefaction of the resulting mass will proceed, at any temperature above zero, to abstract caloric from all adjoining bodies until they are as cold as the mixture. By the addition of crystallized chloride of calcium, or of diluted nitric or sulphuric acid, to snow, a compound may be formed, of which the freezing point is below that at which mercury freezes, or—39°. Housekeepers have latterly availed themselves of the influence of salt, to remove ice from the marble steps at the entrance of their dwellings; as in this way it may be detached without injury to the marble.

Table of Freezing Mixtures.

The following tables are taken from Thomson's Outline of the Sciences of Heat and Electricity, page 191.

Frigorific Mixtures without Ice.

Mixtures.	Parts.	Thermometer sinks,	Degree of cold produced.
Nitrate of ammonia	1	From + 50° to + 4°.	46
Water	1		
Nitrate of ammonia	1	From + 50° to — 7°.	57
Carbonate of soda	1		
Water	1		
Phosphate of soda	9	From + 50° to — 12°.	62
Diluted nitric acid	4		
Phosphate of soda	9	From + 50° to — 21°.	71
Nitrate of ammonia	6		
Diluted nitric acid	4		
Sulphate of soda	8	From + 50° to 0°.	50
Muriatic acid	5		
Sulphate of soda	5	From + 50° to +3°.	47
Diluted sulphuric acid	4		

Frigorific Mixtures with Ice.

Mixtures.	Parts.	Thermometer sinks,	Degree of cold produced.
Snow, or pounded ice	2	From any temp. to — 5°.	
Muriate of soda	1		
Snow, or pounded ice	12	From any temp. to — 25°.	
Muriate of soda	5		
Nitrate of ammonia	5		
Snow	3	From + 32° to — 23°.	55
Diluted sulphuric acid	2		
Snow	8	From + 32° to — 27°.	59
Muriatic acid	5		
Snow	7	From + 32° to — 30°.	62
Diluted nitric acid	4		
Snow	4	From + 32° to — 40°.	72
Muriate of lime	5		
Snow	2	From + 32° to — 50°.	82
Cryst. muriate of lime	3		
Snow	1	From 0° to — 66°.	66
Cryst. muriate of lime	2		
Snow	1	From — 40° to — 73°.	33
Cryst. muriate of lime	3		
Snow	8	From — 68° to — 91°.	23
Diluted sulphuric acid	10		

STATES IN WHICH CALORIC EXISTS IN NATURE.

With two of the modes in which caloric exists in nature, the studen
this Compendium has been made acquainted; and these are the only m
of its existence generally recognised. As it exists in one of them, i
called sensible heat, being susceptible of detection by the senses, or by
thermometer. In the other it is called latent heat, because the quan
present in that mode of existence, is not open to those means of detect
But even in this latent state, caloric is known to be influenced by temp
ture; being liable to be removed entirely from vapours, or liquids, by c
munication with colder substances; so as to render its subsequent prese
in these, a proof of its previous existence in the matter from which it
have been abstracted.

It seems to me, however, that, in some substances, caloric evide
exists in a state in which it is wholly independent of external change
temperature. In this predicament I suppose it to reside in the nitr
chlorates, and fulminates, and generally in all detonating compounds.

If, agreeably to the received chemical doctrines, we are to ascribe
explosive power of such compounds to combined caloric, it must be evi
that its condensation in them is wonderfully great. Yet no good rea
can be assigned for this prodigious condensation. It cannot be ascr
simply to the attraction of ponderable matter; since the same ponder
matter which confines it at one moment, liberates it in the next wit
any adequate assignable cause.

Thus the presence of platinum sponge, a cold metallic congeries, ca
the caloric of a gaseous mixture of hydrogen and oxygen to escape
plosively. An electric spark, or the contact of any ignited matter,
duces the same result. The case of gunpowder, exploded by the igni
of the most minute portion of the mass, is equally unaccountable,
likewise the explosive recomposition of water by a discharge from
same galvanic wires, by which its decomposition may have been effec

The almost irresistible extrication of oxygen in the gaseous state fr
oxygenated water, by contact with the oxide of silver, is still more
point and even more surprising.

The fixation of caloric in detonating compounds, I, therefore, consider
a peculiar state, and due to some peculiar cause, the discovery of whi
would probably unfold many mysteries in galvanism and electro-magn
ism, as well as in chemistry. I deem it more than probable that electric
is the principal agent in these mysterious phenomena.

SECTION III.

LIGHT.

It must necessarily belong to chemistry to treat of lig
so far as it is productive of heat, deoxydizement, a
other chemical effects, and so far as it is evolved
chemical processes.

According to Newton light is a subtile fluid, which
either radiated or reflected from every visible point

the universe, in consequence of its elasticity or the self-repellent power of its particles.

It comes from the sun, about ninety-five millions of miles, in eight minutes, or nearly at the rate of two hundred thousand miles in a second.

Light appears to have no sensible weight. The products of the combustion of phosphorus, carbon, and other combustibles, appear fully equal in weight to the ponderable matter employed. It follows that the loss of the light and heat occasions no diminution of weight; yet enough is emitted by the flame of a candle or lamp to be perceived by many hundred millions of eyes. There is not a luminous point in the universe, from which a sphere of rays is not emitted, in radius equal to any distance from which that point may be seen.

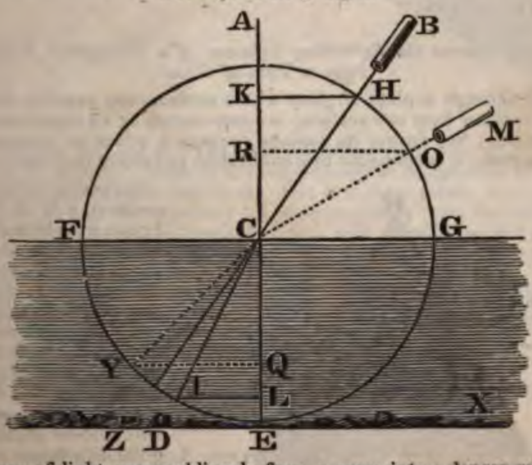
Of the Sources of Light.

As a source of light, the sun is obviously even more prolific than as a source of heat; and it must be evident, that all the processes which produce ignition must also produce light.

There are some cases in which light is emitted without heat. As it comes to us from the moon, as emitted by luminous insects, decayed wood, or the phosphorescent wave, it appears to be unaccompanied by caloric.

In the fire-fly, and in many other insects, it is evolved by vital action.

127. *Refraction of Light.*



When a ray of light passes obliquely from a rarer into a denser medium, it is bent *towards* the perpendicular direction. When the course of the oblique ray is from the denser medium into one which is rarer, it is bent *from* the perpendicular direction.

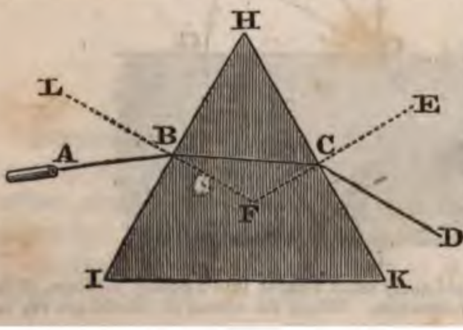
Suppose F G X Z to be a body of water. If a pencil of the solar rays fall upon the surface of the water perpendicularly at C, it will penetrate the water without deviating from its previous course; for whatever may be the attraction between the light and the water, it cannot cause any deflection, since it must act equally on either side of each ray. But should a pencil of rays passing through the tube, B, and penetrating the water at C, reach the bottom, it would shine on the pebble, D; whereas, it would shine upon Z, were the water removed. The light in this case passing from a rarer into a denser medium, and entering the latter obliquely, the rays are attracted by the denser medium most on the side nearest to it, and consequently are bent, or refracted, from their previous course.

About C, as a centre, describe the circle, F H E, and from A draw a diameter, A C E, perpendicular to the surface of the water. Let the lines B C, C I, represent the path of the light in passing from the tube to the bottom of the water. Where these lines intersect the circle, draw K H, I L, parallel to the surface of the water. The angle A C H, which the incident ray makes with the perpendicular, is called the angle of incidence, and K H the sine of this angle. I C E is called the angle of refraction, and I L its sine. In the case of water, the sine I L is always found to be to the sine K H, as 3 to 4; but were a mass of glass substituted for the water, the sine of the angle of refraction to that of incidence would be as 2 to 3, and if the glass were replaced by a similar mass of diamond, the ratio would be nearly as 2 to 5: the ratio being always invariable in the same medium, whatever the angle of incidence may be; for if the pencil of rays were to proceed to C, from a tube at M, making the angle of incidence, A C M, and the angle of refraction, Y C E, the sine, Y Q, would be to the sine, R O, in the same ratio as I L to K H; and this would hold good as before stated, whether F G X Z were water, diamond, crystal, or any other homogeneous and transparent refracting medium. The refraction, which has been thus described as taking place during the passage of rays from air into other denser media, equally ensues when light passes out of such media into the air. Nor is it in air alone that it takes place; it is enough that the substances through which it passes be of different densities, or chemically different in their natures. Combustible liquids or solids have been found to refract most powerfully. It was his discovery of this association between combustibility and refracting power, that led Sir Isaac Newton truly to infer the combustible nature of the diamond, from its superior efficacy in causing refraction.

As an illustration of the case of light refracted, in passing out of denser matter into rarer, let us imagine the eye of an observer placed at the upper orifice of the tube, B, in the figure. Instead of the pebble, Z, which he would see if the water were removed, the pebble, D, will be seen by him. Hence the well known power of water in rendering an object visible, when, in the absence of the liquid, our view would be intercepted by the side of the containing vessel; and hence likewise the broken image which a stick or cord presents to us, when seen partially under water.

128. *Difference between the Refracting Influence of a Triangular Prism, and of a Plate or Pane of Glass.*

In passing through a plate of glass whose surfaces are parallel, the refraction which light sustains from one surface, is compensated by an opposite refraction by the other surface; but during its passage through a prism as represented in the following diagram, it is subjected to a concurrent refraction from two surfaces.



Supposing that the refracting medium, F G X Z, in the last figure, were bounded by air below as well as above, and its upper and lower surfaces were parallel, as in the case of a plate or pane of glass, a ray of light in passing obliquely through it, would be *equally* attracted, on *one side* as it *enters*, on the *other side* as it *emerges*. Hence after its emergence, it will proceed parallel to its original direction.

But should a ray fall upon a

prism, as represented in the foregoing figure, in the direction of the line, A B; agreeably to the preceding demonstration, it will, on account of the obliquity of its approach, be refracted towards C, and emerging from C, obliquely to another surface of the prism, H C K, it will be again most attracted by that portion of the surface towards which it inclines. Consequently, it will be refracted so as to proceed in the direction C D.

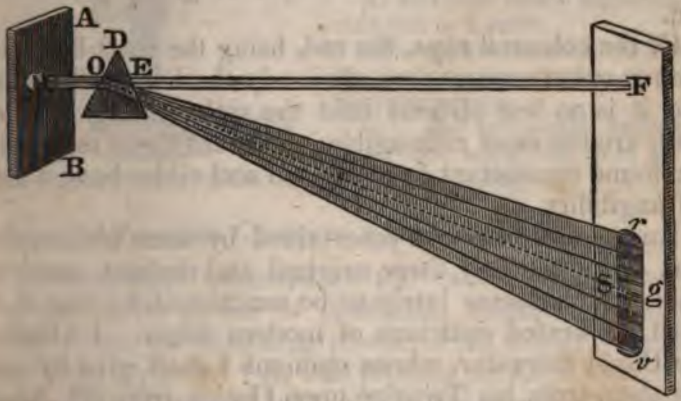
Thus it must be evident that the two surfaces of the prism have a concurrent influence in bending the rays from their previous course; while in the pane, the influence of one surface is compensated by that of the other.

The lines, L F and E F, being perpendiculars to the surfaces of the prism, A B L is the angle of incidence, and F B C, the angle of refraction, to the surface at which the rays enter the prism. F C B is the angle of incidence, and E C D, the angle of refraction to the surface from which the rays emerge.

129. *Dispersion of Light.*

Besides the refraction sustained by a pencil of rays, agreeably to the preceding illustration, they undergo another alteration, the effects of which are very pleasing, and, agreeably to the doctrine of Newton, highly instructive, being the foundation of his theory of colours.

Light appears to consist of particles of different kinds; each kind having the property of producing on the retina of the eye a peculiar impression, which being conveyed to the sensorium creates the idea of a colour. The rays thus capable of acting differently on the retina, seem to be unequally susceptible of refraction. Hence, in passing through the prism, they are separated from each other, forming a beautiful series of all the various colours of the rainbow, in an oblong figure called the spectrum. Under these circumstances, the rays are said to be dispersed, and the process by which they are separated is called dispersion.



Let A B represent a part of a window shutter of a room, into which light enters only through the hole C. If the light thus entering be received on a screen, a circular spot on it will be made luminous. But if a glass prism, D O E, be placed before the hole, so that the light may fall advantageously upon the prism, the rays, which had before produced the luminous circle, will be refracted and dispersed, so as to form the spectrum, *r g v*, consisting of the following colours, arranged in the following order—red, orange, yellow, green, blue, indigo, violet.

The red rays are found to be pre-eminent in heating power; the violet as remarkable for their superior influence in certain chemical changes, dependent on deoxidation.

Of the Heating, Illuminating, and Chemical Properties of the Rays.

In the middle of the spectrum, the rays have the highest power of illumination.

Besides the rays thus mentioned, there are invisible, heat-producing rays beyond the red, and invisible rays producing deoxidation beyond the violet. Herschel, to whom we are indebted for the discovery of these invisible rays, was of opinion that the greatest heating and deoxidizing power existed in them just beyond the limits of the visible spectrum.

From experiments made by Seebeck and Mellone, it appears that the location of the principal heating power is dependent on the nature of the refracting medium. A variety of transparent liquid media have been employed, by causing them to occupy the cavities of hollow glass prisms. It was found that when the prism was occupied by water or alcohol, the maximum of heat was in the yellow rays; when it was filled with sulphuric acid, or solutions of sal ammoniac or corrosive sublimate, the maximum heat was in the orange. In the spectrum produced by crown or plate glass, the principal heat was in the red, and in that procured by flint glass, beyond the red.

Of the coloured rays, the red, being the least bent from their previous course, are obviously the least refrangible; and it is no less obvious that the violet, being the most bent, are the most refrangible; also that those rays which are found equidistant from the red and violet have a mean refrangibility.

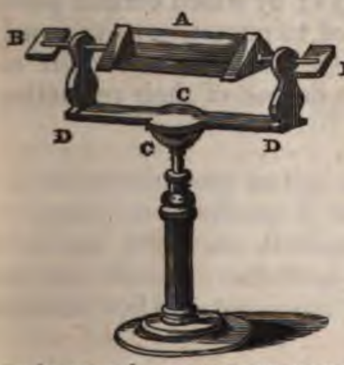
An opinion has been entertained by some philosophers that there are only three original and distinct species of light, which seems lately to be sanctioned by one of the most celebrated opticians of modern times. I allude to Sir David Brewster, whose opinions I shall give by quoting them from his Treatise upon Optics, page 68, American edition.

> "With the view of obtaining a complete analysis of the spectrum, I have examined the spectra produced by various bodies, and the changes which they undergo by absorption when viewed through various coloured media, and I find that the colour of every part of the spectrum may be changed not only in intensity, but in colour, by the action of particular media; and from these observations, which it would be out of place here to detail, I conclude that the solar spectrum consists of three spectra of equal lengths, viz. a *red* spectrum, a *yellow* spectrum, and a *blue* spectrum. The *primary red* spectrum has its maximum of intensity about the middle of the *red* space in the solar spectrum, the *primary yellow* spectrum has its maximum in the middle of the *yellow* space, and the *primary blue* spectrum has its maximum between the *blue* and the *indigo* space. The two minima of each of the three primary spectra coincide at the two extremities of the solar spectrum.
>
> "From this view of the constitution of the solar spectrum we may draw the following conclusions:—
>
> "1. *Red*, *yellow*, and *blue* light exist at every point of the solar spectrum.

"2. As a certain portion of *red*, *yellow*, and *blue* constitute *white* light, the colour of every point of the spectrum may be considered as consisting of the predominating colour at any point mixed with white light. In the red space there is more red than is necessary to make white light with the small portions of yellow and blue which exist there; in the yellow space there is more yellow than is necessary to make white light with the red and blue; and in the part of the blue space which appears violet there is more red than yellow, and hence the excess of red forms a violet with the blue.

"3. By absorbing the excess of any colour at any point of the spectrum above what is necessary to form white light, we may actually cause white light to appear at that point; and this white light will possess the remarkable property of remaining white after any number of refractions, and of being decomposable only by absorption. Such a white light I have succeeded in developing in different parts of the spectrum. These views harmonize in a remarkable manner with the hypothesis of three colours, which has been adopted by many philosophers, and which others had rejected from its incompatibility with the phenomena of the spectrum."

130. *Triangular Glass Prism, conveniently mounted on a universal Joint.*



This figure represents a triangular glass prism, mounted on a universal joint, supported by a brass stand, so as to be well qualified for the dispersion of light, agreeably to the experiments alluded to in the preceding article.

A, the glass prism, supported at each end by a pivot.

B B, handles by means of which the pivots are turned, so as to make the prism revolve.

C, C, ball and socket, forming a joint, upon which the plate, D D, may be moved so as to assume any serviceable position.

Of certain Chemical Effects of Light.

I have already adverted to the calorific influence of light, and to its power of producing chemical changes. Among these, the bleaching power of the solar rays is familiar to every body. In this process the rays appear to exercise that modifying influence on the attraction of ponderable matter alluded to at page 3. Consequently a new arrangement of particles ensues in lieu of that which formed the colouring matter. Certain vegetable leaves, if exposed to the sun in water, have been found to yield oxygen gas. Some metallic salts, especially nitrate of silver, are blackened by a like exposure, owing, as is alleged, to deoxidation. A mixture of hydrogen and chlorine will, in the dark, remain for a long time without combining; but in the rays of the sun will explode.

According to Berzelius, the power of producing this result exists only in the violet rays.

Polarization of Light.

This name has been given to a property of light, which causes it often to be divided into two portions, one of which is transmitted, the other reflected, by the same pane of glass: or one portion sustains refraction in an ordinary degree, the other in an extraordinary degree. Again, all these properties are found to be commutable, so that the portion of the rays which is reflected in one case, may be transmitted in another; or that which in one case sustains the ordinary refraction, in another may undergo the extraordinary refraction, and vice versa.

These phenomena are ascribed to the different positions assumed by different sets of rays; by which certain poles, which the particles are supposed to possess, are variously directed at different times, so as to determine their reflection or transmission, or the degree of their refraction.

PART II.

PONDERABLE SUBSTANCES.

[Ponderable substances are conveniently divided into *Inorganic Substances*, or those derived from the mineral kingdom, and *Organic Substances*, or those derived from the vegetable and animal kingdoms.]

---

inorganic substances

INORGANIC SUBSTANCES.

[As introductory to the consideration of the individual inorganic substances, it will be expedient to treat of *Chemical Attraction*, *Definite Proportions*, *Specific Gravity*, and the *Mode of collecting and preserving Gases*. These subjects will be considered in the four following sections.]

SECTION I.

OF CHEMICAL ATTRACTION.

The word chemical has been used to designate the attraction which takes place between heterogeneous particles only. I object to this restriction of its meaning, because I consider it as affording a natural line of separation between chemical and mechanical philosophy, to consider the one as treating of masses, or masses and particles, the other of particles only. Besides, the process of crystallization, of which I shall in the next place treat, arises from the reaction of homogeneous atoms; and it was among chemists that the investigation or observation of the laws and phenomena of crystallization originated. I consider crystallography as a branch of chemistry, and the attraction which causes homogeneous atoms to cohere, whether in the crystalline form or otherwise, as a species of chemical attraction.

The attraction which takes place between homogeneous particles, is designated as *attraction of aggregation*, *attraction of cohesion*, or *homogeneous attraction*. The attraction which arises between heterogeneous particles, is called *chemical affinity*, or *heterogeneous attraction*.

OF ATTRACTION OF AGGREGATION OR COHESION, OR HOMOGENEOUS ATTRACTION.

Of this kind is the force which enables bodies to resist mechanical division. Overcoming it does not alter the *chemical* nature of a substance. It is the cause of crystallization.

Of Crystallization.

Almost all matter, in passing from the fluid to the solid state, assumes regular forms called crystals.

As it is difficult to conceive that homogeneous atoms are not exactly similar in size and shape, it is not wonderful that when united by the same attractive force, they should produce regular forms. To produce irregular forms, the atoms, or the forces actuating them, should be irregular. In fact, as the deposition of matter from solution, or on the evaporation of the solvent, is accelerated or retarded, a corresponding change ensues in the crystalline form. In this way various deviations arise from the primary form, which is assumed under circumstances which allow the deposition to proceed at the same rate precisely. Those forms which deviate from the primary form are called secondary. The various steps by which they are generated from the primitive forms, have been most ingeniously traced, or inferred, by Hauy and others. In some instances, the primitive form has been developed by cleavage.

It was at one time the general impression that every chemical compound had an appropriate crystalline form. Latterly it has been shown that certain substances quite different in their nature, as for instance phosphoric and arsenic acids, assume the same forms in crystallizing. Such substances are said to be *isomorphous*.

In the introduction to Thomson's Inorganic Chemistry, several groups of isomorphous substances are mentioned.

Other things being equal, crystals are larger in proportion as their growth is slower. They shoot from extraneous bodies, as the sides of the receptacle, or from strings or sticks, in preference to crystallizing in an isolated manner. Agitation hastens their production but confuses them. The crystalline texture of some of the trap rocks is attributed to slow cooling. The same matter fused and allowed less time to cool forms a glass.

Berzelius alleges that, if two flasks, both containing a saturated solution of two parts of nitrate of potash and one of sulphate of soda, be surrounded with ice or cold water, on introducing a crystal of nitrate of potash into one and a crystal of sulphate of soda into the other, crystals will be formed of the same nature as that of the crystal introduced into each flask. Nitrate of potash will be found crystallized in the flask first mentioned, and sulphate of soda as exclusively in the other.

Crystals are found in nature and are produced artificially.

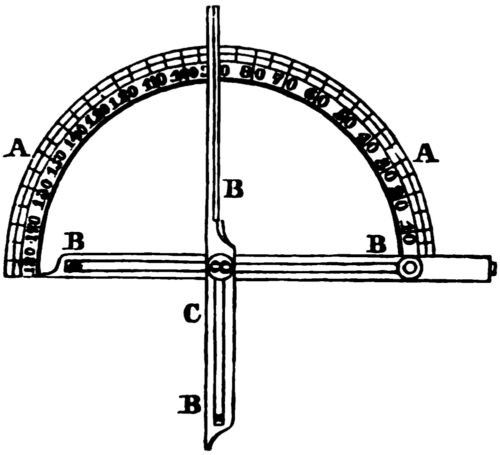
The precious stones are native crystals. Carbonate of lime, common salt, and gypsum are native products, often crystalline in form.

Of the Goniometer, or Instrument for measuring the Angles of Crystals.

Crystals may appear to be exactly similar to the eye; but when compared by means of accurate instruments called goniometers, they will often be found to differ in their angles. Of these instruments there are two constructions; one, being more easy to be used, is of more general utility; the other, contrived by Wollaston, is complicated, but when skilfully employed is capable of giving more accurate results.

The instrument of the easiest application, and which is usually employed, is represented by the following engraving.

Of the Common Goniometer.



Its construction is founded upon the 15th proposition of Euclid, which demonstrates that the opposite angles, made by any two lines in crossing each other, are equal. Hence it follows that the angles made by the legs, B B, B C B, of this instrument, above and below the pivot on which they revolve, are equal to each other. Consequently, if they be made to close upon any solid crystalline angle, presented to them at C, they will comprise a similar angle on the other side of the centre about which they turn. This angle is evidently equivalent to that of the crystal, and is ascertained by inspecting the semicircle, A, graduated into 180 degrees, precisely in the same manner as a protractor.

The construction of goniometers is usually such as to allow the legs to be detached from the arch, in order to facilitate their application to crystalline angles; and yet, so that they may be reapplied to the semicircle, without deranging them from the angle to which they may have been adjusted.

The piece of brass, in which the pivot is fastened, slides in a slit in each leg; so as to permit them to be made of a suitable length, on the side on which the crystal is applied.

Of Wollaston's Goniometer.

The process by which angles are ascertained by means of Wollaston's goniometer is as follows:—

The crystal to be examined is attached to an axis, and so adjusted, by means of suitable mechanism, that the image of a window bar may be seen reflected from one of the crystalline faces, so as to coincide with a line (seen directly) drawn on the wall under the window, parallel to the window bar. By a partial revolution of the axis, and consequently of the crystal, a similar coincidence of the images of the bar and line is produced by means of another face of the crystal, being the next to that first employed.

Meanwhile the number of degrees of a circle moved through, in changing the crystal from the first to the second position, is measured by an index on a graduated arch, and the degrees of the angle, which the surfaces make with each other, thus ascertained.

Various Modes of causing Artificial Crystallization.

Fusion followed by congelation.—Instances: Crystallized sulphur, bismuth, antimony, zinc.

Solution followed by evaporation in open vessels.—Exemplified by salts, acids, alkalies, sugar.

Solution with heat followed by refrigeration.—Most of the substances which crystallize by evaporation, yield crystals in this way.

Solution followed by vaporization at the boiling heat.—Crystals may be thus obtained from many salts, but are always minute.

Solution followed by saturation.—Instances: Potash saturated by carbonic acid or chlorine.

Sublimation.—This comprises the idea of vaporization, and condensation into a state of solidity. Instances: Corrosive sublimate, calomel, iodine, arsenic.

Solution followed by precipitation; as in the case of the arbor Dianæ and arbor Saturni.

131. *Crystalline Specimens exhibited.*

A wooden arch, about fifteen inches high and a foot wide, encrusted with fine blue crystals of the sulphate of copper.

Crystals of corrosive sublimate and calomel.

Crystals of sulphur, arsenic, bismuth, antimony, &c.

Of Decrystallization.

It has been ascertained by Mr. Daniell that crystals may be partially developed by solution. When alum is slowly dissolved, its crystalline structure becomes very evident.

Of Water of Crystallization.

The well known spiculæ, which, by their appearance on the surface of water, indicate incipient freezing, are crystals. In fact, it was from the Greek name for ice, κρυσταλλος, that the word crystal was adopted; as crystals were correctly considered as the products of a process analogous to freezing. This is strictly true in the case of crystals resulting from the congelation of matter from a state of fusion. Water enters into the constitution of many crystals which, when robbed of it by heat or desiccation, lose the crystalline form. The water thus situated is called water of crystallization. Some substances combine with water in different proportions, and consequently assume different forms; others crystallize with or without water, with a corresponding diversity of form. These results are dependent upon variations of temperature in the solvent at the period of the crystallization. At 86°, sulphate of soda crystallizes without, at 40°, with water of crystallization. Chloride of sodium, which is ordinarily anhydrous, is made to unite with water of crystallization at 8° below zero.

Crystals usually hold within their crevices more or less of the solution in which they have been crystallized. Hence the decrepitation of chloride of sodium and other anhydrous salts when heated, from the vaporization of the water so held. The larger the crystals, the more they are subject to this impurity.

Of the Consequences of excluding the Air from a saturated Solution of Sulphate of Soda while boiling.

Several matrasses are sealed, so as to be air-tight, while containing a *boiling saturated solution of Glauber's* *salt*. The solution remains liquid, so long as undisturbed, but on the admission of the air, will often become a compact crystalline mass within a few seconds. In other cases, it will continue liquid for some time, even for 24 hours, and may then crystallize on being poured out of the matrass. Sometimes it crystallizes in the neck of the vessel while the operator is pouring it out; at others, allowing a crystal or other body to fall into the solution, causes crystals to shoot. No satisfactory explanation has been afforded of this phenomenon. It seems as if the repulsive and attractive powers were so nearly balanced as to enable a slight external force to determine the preponderancy in favour of the latter. That there is an evolution of caloric, consequent to the congelation, is rendered evident by a rise of temperature.

132. *Experimental Illustration*.

A solution of sulphate of soda, saturated at a boiling heat and sealed up air-tight in a glass flask, remains liquid until it is opened, and then crystallizes either spontaneously or from slight causes.*

OF CHEMICAL AFFINITY, OR HETEROGENEOUS ATTRACTION.

This attraction is never subdued mechanically, unless when nearly balanced by repulsion; as in the case of compounds which may be exploded by percussion, or of elastic fluids combined with liquids. See article 99.

To sever elements, united by chemical affinity, the finest edge producible by human art is utterly incompetent. Thus, chalk consists of lime and carbonic acid; vermilion, of sulphur and mercury. Yet when reduced to powders perfectly impalpable, the minutest particle, whether of chalk or vermilion, contains the same ingredients as the mass, and in the same proportion.

---

* The details of crystallography, as they have been presented by Hauy and others, are of themselves so copious, as to require greater exertion of the memory than all the chemistry which I would expect a candidate for graduation to learn. It is one of those subjects of which the acquisition may be advantageously postponed, until much other knowledge has been acquired. Consequently as this preliminary knowledge is more than sufficient to occupy all the time which is allotted to my course of lectures, I have omitted some pages respecting crystallization which were introduced into the last edition of this work.

Different Cases of Affinity.

First Case—Simple Combination.—A and B, two heterogeneous substances, unite and form the compound A B.

Instances.

Copper with zinc forms brass.
„ with tin, „ bronze.
Antimony with lead forms type metal.
Magnesia with sulphuric acid forms Epsom salt, or sulphate of magnesia.
Soda with sulphuric acid forms Glauber's salt, or sulphate of soda.
With mercury, various metals form amalgams.

133. *Experimental Illustration.*

A portion of gold leaf, being triturated with mercury, disappears, forming a chemical compound with the mercury, in consequence of the inherent attraction or affinity between the heterogeneous particles.

Second Case of Affinity.—Called *single elective attraction, or simple affinity.*

A and B, two heterogeneous particles, being united in the compound AB, C, another particle, being blended with them in solution, unites with one of them, as A, to the exclusion of B.

In this case, C is said to decompose AB, and to have a greater affinity for A than for B.

134. *Experimental Illustration.*

Potash being added to a solution of sulphate of magnesia, the magnesia precipitates in white flocks. A like result takes place on adding a solution of potash to a solution of sulphate of alumina.

Rationale.—Sulphate of magnesia consists, as its name implies, of sulphuric acid and magnesia. The affinity existing between the potash and the acid being greater than between the acid and the magnesia, the latter is displaced from combination, and, being by itself insoluble, precipitates. An analogous explanation will apply in the case of the alumina. In each case, the affinity of the acid for the alkali predominates over that of the acid for the earth.

Third Case of Affinity.—Called *double elective attraction, or complex affinity.*

The compound formed by the particles A and B, being blended in solution with the compound formed by C and D,—A combines with D, and B with C.

135. *Experimental Illustration.*

A B		A D
Sulphate of zinc being mixed with Acetate of lead,	forms	Sulphate of lead and Acetate of zinc.
C D		C B

Fourth Case of Affinity.—A and B being in union, C, added in *excess*, combines with both A and B.

When ammonia is added to certain solutions of metallic salts, those of copper or silver for instance, it operates at first as the potash does in the case of single elective attraction abovementioned, and the oxide of copper or silver precipitates. But if the ammonia be added in such quantity, as that, after all the acid shall have been saturated, there shall be an excess of alkali, this excess will combine with the precipitated metallic oxide, forming with it a soluble compound which dissolves. Hence the menstruum which is at first rendered turbid, afterwards becomes clear, and, in the case of the copper, assumes a beautiful and characteristic blue colour.

136. *Experimental Illustration.*

Liquid ammonia being poured into a solution of copper, at first precipitates the metal in green flocks; but, when the alkali is added in excess, these flocks disappear, and a beautiful blue solution results.

137. *Additional Illustrations of Chemical Affinity.*

In order to show the wonderful power of chemical reagents in producing striking changes, some additional exemplifications of chemical affinity will here be given. This exhibition may excite curiosity in the learner and afford gratification, although unprepared to understand the intricate play of affinities by which the results are accomplished.

Experiments.

Silver precipitated by mercury, mercury by copper, and copper by iron.

Conversion of two liquids into an adhesive mass by mingling sulphuric acid with a solution of muriate or nitrate of lime.

Solution of ferroprussiate of potash, added to solutions of copper and iron.

Solution of chromate of potash, added to solutions of lead, mercury, and silver.

Ammoniacal nitrate of copper or silver, added to arsenious acid.

Of Cohesion as an Opponent to Chemical Combination.

There are many substances, among others carbon, which, under certain forms, in consequence of greater hardness, are much less susceptible of chemical reaction, than under others. Thus the diamond, anthracite, charcoal, and tinder are varieties of carbon, which are endowed with a susceptibility of combustion inversely as their hardness. Tinder is proverbially ready to take fire, while the diamond is only to be ignited by the aid of extreme heat, and an unusual supply of oxygen. Magnesia and lime, after exposure to the flame of the compound blowpipe, become almost insusceptible of the action of acids, which otherwise would readily dissolve them. In these cases, it would really appear that the attraction between the homogeneous atoms counteracts the heterogeneous affinity which would sever them. Yet I conceive it to be an error to confound the obstruction to chemical reaction thus created, with that which arises from the restriction of the surface in contact with the solvent. Other things being equal, there will evidently be more action in proportion as the points of contiguity are multiplied, and vice versa. Thus the action of an acid will be less rapid upon a metallic ball, than upon the same weight of metal in the state of foil, fine wire, or turnings;

although the attraction of the homogeneous particles is quite as energetic in the one case as in the other.

138. *Effects of Mechanical Division experimentally illustrated.*

If a ball of brass be put into one glass, and only half its weight of brass filings or turnings into another, on adding nitric acid to both, a violent effervescence will ensue in the one, while in the other, the reaction will hardly be discernible.

139. *Influence of Solution in promoting Chemical Reaction, experimentally illustrated.*

Tartaric acid and a carbonate, although intimately intermingled in a pulverulent state, do not react until moistened, when a lively effervescence ensues.

140. *Exception to the Law that Chemical Action requires Fluidity, experimentally illustrated.*

If slaked lime and muriate of ammonia in powder be mixed, the pungent fumes of ammonia will be perceived.

Tables of Affinity.

These consist of a series of substances, placed in a column, in the order of their affinity for any one substance at the head of the column. The following is an example:—

Sulphuric Acid.

Baryta,
Strontia,
Potash,
Soda,
Lime,
Magnesia,
Ammonia.

SECTION II.

OF DEFINITE PROPORTIONS.

The proportions have been long known to be invariable, in which substances must be mixed in order to saturate each other, or to produce a compound in which the peculiar characters, or affinities of the ingredients, are extinguished.

When substances combine in other proportions than those of saturation, their ratio is no less definite and constant.

There is not in any case, except the peculiar one of solution, an indefinite gradation in the proportions in which bodies combine. There are rarely more than four gradations.

The number, representing the least proportion in which a substance is known to combine, will, in a great majority of cases, divide the numbers representing the greater proportions without a fraction; and where this result is unattainable, it will still be found that the larger proportion may be divided by the half of the lesser without a remainder.

Let A, B, and C be certain substances, and let X, Y, and Z be other substances, severally having an affinity for either A, or B, or C. Let each of the former and each of the latter be combined in the least possible proportion. Consequently, the least combining proportion of each substance will be found three times. It will appear that the proportions of A, B, and C, found by combining them with X, will be in the same ratios to each other, as the proportions found by combining them with Y, or Z; and reciprocally, that the proportions of X, Y, and Z, will have the same ratios, whether ascertained by their combination with A, B, or C.

When, instead of ascertaining the least combining proportions of six substances, the experiment has been extended to any larger number, the same uniformity has been found to prevail in the ratios of the numbers representing those proportions. It has also been found that when numbers are ascertained which express the ratio of the least combining proportions of a variety of substances to any one substance, as for instance to oxygen, those numbers will express the ratios of the least combining proportions of the substances in question to each other.

Numbers representing *least combining proportions* are called *chemical equivalents.* As they are merely expressive of ratio, they may be multiplied by any common multiplier, or divided by any common divisor, without affecting their correctness.

They are usually so computed as to make the equivalent of oxygen, or of hydrogen = 1. As the equivalents of these substances are as 1 to 8, it follows that if hydrogen be represented by unity, oxygen will be 8. If oxygen be unity, hydrogen will be 0.125, or one-eighth of one. Consequently, equivalents, formed upon either basis, may be converted into those corresponding with the other, either by multiplying or dividing by 8.

By Berzelius, Wollaston, and Thomson, oxygen has been made the standard. Berzelius assumes it at 100, Wollaston at 10, and Dr. Thomson at 1. The only difference between the equivalents founded upon these numbers, is in the position of the decimal point.

Of Tables of Chemical Equivalents.[*]

In these the equivalents of all known bodies, so far as ascertained, are arranged alphabetically.

Such tables are of great utility in practical chemistry. The operative chemist may frequently resort to them with advantage. They enable him to store his memory with data adequate to the solution of a great number of questions which must necessarily arise. If he wishes to know how much of any two substances he must take to form a third, he has only to recollect or look for their equivalents in the table, and seek a solution by the rule of three. For as the equivalents of the substances are to each other, so are the quantities of them to be used. Should it be an object to produce only a certain weight of a compound, then as the equivalent of the compound, is to that of either of the ingredients, so is the weight of the compound required, to the requisite weight of either ingredient.

In order to know how much of the proper materials he must use to effect a decomposition, he has only to employ them in the ratio of their respective equivalents.

Moreover, when the proportions, afforded by analysis, do not harmonize with well ascertained equivalents, we are warned of the existence of some inaccuracy, which in many cases may be safely corrected so as to make the results accord with them.

141. *Wollaston's Scale of Equivalents.*

This instrument is so constructed that the computation requisite in using the equivalents is performed by a slide.

It has been mentioned that the equivalents may be expressed in any numbers having the same ratios to each other as the least combining proportions of the substances which they represent. The slide enables us to adopt any such numbers as may be convenient. Equal distances on the slide give the same ratios in different numbers. If, by moving the slide, we vary one equivalent to 100 for instance, the other equivalents vary proportionably.

Of the Atomic Theory.

Extension has been proved to be infinitely divisible, and it is not difficult to suppose that the matter, comprised within any given limits, may be susceptible of as many subdivisions as the space in which it is contained. On the other hand, it is obvious, that *mechanical* division must be limited by the imperfection of the edges or surfaces employed to accomplish it.

Were atoms chemically divisible ad infinitum, any one substance, however small in quantity, might be diffused, in a state of chemical combination, throughout any other, having an affinity for it, however great; for as no one particle in the latter would exercise a stronger affinity than another, it would be unreasonable to suppose that each should not have its share. That such a diffusion is impracticable must be evident from the smallness of the number of definite proportions to which substances in combining are restricted, as already mentioned when upon the subject of equivalents. Hence elementary atoms are not considered as liable to an unlimited subdivision, either by chemical or mechanical agency.

The ratios of the equivalent numbers are supposed to be dependent on, and identical with, those of the weights of the integrant atoms of the substances to which they appertain. Thus the fact that 32 parts by weight of soda will saturate as much of any acid as 48 parts of potash, is explained by supposing that the weights of the smallest atoms of those alkalies which can exist, are to each other as 32 to 48.

---

[*] See Appendix for a Table of Equivalents.

In like manner it is explained that, when neutral salts are made reciprocally to decompose each other, no excess of either ingredient is in any case observable. The lime in nitrate of lime is to the potash in an equivalent weight of the sulphate of potash, as 28 to 48, yet neither is the lime incompetent to take the place of the potash, nor is there too much potash to take the place of the lime. This result is intelligible, if we suppose that, when quantities just adequate for reciprocal decomposition are employed, there is an equal number of atoms of each salt; the one containing as many atoms of potash weighing 48, as the other contains atoms of lime weighing 28.

The same explanation applies to the fact that, while the sulphuric acid in the sulphate of potash is to the nitric acid in the nitrate of lime as 40 to 54, yet there is neither too much of the latter acid nor too little of the former, to produce neutral compounds with the bases to which they are severally transferred.

On account of the hypothetical association of the numbers, representing the least proportions in which bodies are known to combine, with the supposed relative weight of their atoms, those numbers are as well known by the appellation of *atomic weights*, as by that of *chemical equivalents*.

Of Chemical Symbols.

I shall translate from Berzelius an account of the symbols which he has devised, and which it would be well to understand, as they will often be met with. Objections have been made to some part of his plan, but in general I believe it will be expedient to adhere to it; since whatever Berzelius recommends, awakens the attention of chemists universally, and must cause his symbols to be generally understood throughout the chemical world.

"We select (says he) as symbols the initial letters of the latin names of bodies. When the names of several bodies have the same initial, we add to each a letter which it has not in common with the rest; as, for instance, C signifies carbon, Cl chlorine, Cr chromium, Cu copper, Co cobalt. When, however, the names of a metallic and non-metallic element commence with the same letter, no additional letter is added to the latter. But when two non-metallic elements have a common initial, it is necessary to distinguish one by means of an additional letter. Thus, to distinguish chlorine, bromine, and silicon, severally, from carbon, boron, and sulphur, the symbols of the former are Cl, Br, and Si, while those of the latter are, simply C, B, and S.

"The number of atoms is designated by cyphers. A cypher placed to the left multiplies all the symbols to the right, as far as the first cross, + or the whole formula. A little cypher situated to the right of a symbol, and a little above its level, multiplies that symbol only. Thus S^2O^5 signifies *one* atom of hyposulphuric acid, consisting of two atoms of sulphur and five of oxygen; while $2S^2O^5$ signifies *two* atoms of the same acid. In such cases as that just cited, in which two atoms of the radical are united with one, three, or five of oxygen, the expression for the former would be abbreviated advantageously by having a specific sign for a double atom. The sign which I have adopted for this purpose, is a dash across the lower part of the symbolic letter. Thus P signifies a single atom, $\underline{\text{P}}$* a double atom of phosphorus. Compound atoms of the first order are expressed as in the following example of sulphate of copper—$\text{CuO}+\text{SO}^3$. The trisulphate of the sesquioxide of iron would be expressed by $\underline{\text{Fe}}\text{O}^3+3\text{SO}^3$.

"It may be expedient to designate the number of atoms of oxygen by dots placed over the letters symbolic of radicals. Thus we may designate the sulphate of copper by $\dot{\text{Cu}}\dddot{\text{S}}$, the trisulphate of the sesquioxide of iron, by $\underline{\dddot{\text{Fe}}}\dddot{\text{S}}^3$."

List of the Atomic Weights of the Simple Ponderable Substances, together with their Symbols.

As the atomic numbers are practically useful, enabling us to know the proportions in which substances are combined, or in which they should be used to produce compounds, it is advantageous to commit them to memory as far as possible. The whole number of substances recognised as elementary, agreeably to the present state of our knowledge, is fifty-four. Of these, little more than half are of sufficiently frequent recurrence either in speculation or in practice, to make it desirable to remember their numbers. I will quote them, therefore, in two distinct tables. Those of which a knowledge is likely to be rarely in demand, I have subjoined in smaller type. The symbols are given in a separate column. In obedience to the example of the British chemists, I employ Po and So, instead of K and Na, as the symbols of potassium and sodium.

	Symbol.	At. Wts.		Symbol.	At. Wts.
Aluminium	Al	14	Lithium	L	6
Antimony	Sb	64	Magnesium	Mg	12
Arsenic	As	38	Mercury	Hg	202
Barium	Ba	69	Nitrogen	N	14
Bismuth	Bi	71	Oxygen	O	8
Boron	B	11	Phosphorus	P	16
Bromine	Br	78	Platinum	Pl	99
Calcium	Ca	20	Potassium	Po	40
Carbon	C	6	Selenium	Se	40
Chlorine	Cl	36	Silicon	Si	8
Copper	Cu	32	Silver	Ag	108
Fluorine	F	18	Sodium	So	24
Gold	Au	200	Strontium	Sr	44
Hydrogen	H	1	Sulphur	S	16
Iodine	I	126	Tellurium	Te	64
Iron	Fe	28	Tin	Sn	59
Lead	Pb	104	Zinc	Zn	32

Cadmium	Cd	56	Osmium	Os	100
Cerium	Ce	46	Palladium	Pd	53
Chromium	Cr	28	Rhodium	R	52
Cobalt	Co	30	Thorium	Th	60
Columbium	Ta	185	Titanium	Ti	24
Glucinium	G	18	Tungsten	W	95
Iridium	Ir	99	Uranium	U	217
Manganese	Mn	28	Vanadium	V	69
Molybdenum	Mo	48	Yttrium	Y	32
Nickel	Ni	30	Zirconion	Zr	34

---

* Instead of placing the dash across the lower part of the letter, it is generally *placed under it*, as the former mode requires type cast for the purpose.

It appears from some experiments made by Messrs. Petit and Dulong, that the capacities for heat, or specific heats, of all elementary atoms are the same; so that if the specific heat of any one congeries of atoms be less than that of another having the same weight, it is because the atoms of the one being heavier than those of the other, there are fewer of them in the same weight. Hence as the capacities, or specific heats, of elementary substances are greater as estimated in the mass, the weights of their atoms are less; so that if, in the case of each, its atomic weight be multiplied by its specific heat, the product will in general be so nearly the same, that the difference may be ascribed to the inaccuracy unavoidable in experimental investigations.

Respecting this highly important and interesting inference of Petit and Dulong, Professor A. D. Bache has endeavoured to show in an article published in the Journal of the Academy of Natural Sciences, that multiplying the equivalents of twelve principal metals into their specific heat, gives results so widely deviating from uniformity as to take all plausibility from the hypothesis that the atoms of simple bodies have the same specific heat.

Dr. Thomson has observed that this law is more likely to be true, since it holds good without doubt in the case of the gases; and that if it be true we have only to divide the specific heat of hydrogen by the atomic weight of any body, to find its specific heat. Moreover that the specific heats thus found agree very nearly with those ascertained experimentally.

◆

SECTION III.

OF SPECIFIC GRAVITY.

A clear idea of specific gravity is indispensable to a chemist. ***Gravity*** and ***weight*** are synonymous words; but the term ***specific gravity*** is used to signify the ratio of ***weight*** to ***bulk***. Hence the object of all the processes for ascertaining specific gravities, is either to ascertain the ***weight*** of a ***known bulk***, or the ***bulk*** of a ***known weight;*** for whether the substances whose specific gravities are to be found be reduced to the same weight and then measured, or be reduced to the same bulk and then weighed, the ratio of their weights to their bulks will be discovered. If reduced to the ***same bulk*** and ***weighed***, their ***specific gravities*** will be ***directly*** as the ***weights***. If reduced to the ***same weight and measured***, their ***specific gravities*** will be ***inversely*** as their ***bulks*** thus ascertained.

Supposing a like bulk of each kind of matter in nature to be weighed, the results, numerically stated, would represent their specific gravities. But since it is not possible to procure an exactly similar bulk of each kind of matter, it is necessary to resort to another mode of reducing their bulks to a common measure. The method adopted in the case of solids and liquids, is to divide the weight of a given bulk of each body of which the specific gravity is to be found, by the weight of a like bulk of water. This in fact may be stated as the general rule for ascertaining specific gravities.

Thus on dividing the weight of any bulk of copper by the weight of a like bulk of water, the quotient is 9. This, therefore, is received as the specific gravity of copper. By a similar procedure, in the case of silver, the quotient is 10.5, in the case of mercury 13.6, in the case of gold, 19.3: consequently, these numbers are considered as representing the specific gravities of those metals.

If the body be lighter than water, as in the case of cork which is only about one-fifth as heavy, the quotient, being less than one, is expressed by a decimal fraction. Thus the specific gravity of cork may be stated to be .2.

The gravity of water has been assumed as the standard, because this liquid may always be obtained sufficiently pure; and it is generally easy to ascertain the weight of a quantity of it, equal in bulk to any other body.

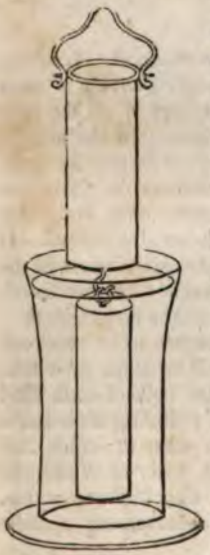
The weight of a quantity of water, equal to the body in bulk, is equal to the resistance which the body encounters in sinking in water. Hence, if we can ascertain, in weight, what is necessary to overcome the resistance which a body encounters in sinking in water, and divide by the weight thus ascertained, the weight of the body, we shall have its specific gravity.

In the case of a body which will sink of itself, the resistance to its sinking is what it loses of its weight when weighed in water.

In the case of a body which will not sink of itself, the resistance to its sinking is equivalent to its own weight, added to the weight which must be used to make it sink.

142. *Experimental Demonstration that the Resistance which a Body encounters in sinking in any Liquid, is just equivalent to the Weight of a portion of the Liquid equalling the Body in bulk.*

This proposition may be experimentally demonstrated, by means of the apparatus represented by the following figure.



The cylinder, represented as surrounded by the water of the vase, is made to fit the cavity of the cylinder suspended over it so exactly, that it enters the cylinder with difficulty, on account of the included air, which can only be made to pass by it slowly. It must, therefore, be evident, that the cavity of the hollow cylinder is just equal in bulk to the solid cylinder.

Both cylinders (suspended as seen in the figure) being counterpoised accurately upon a scale beam, let a vessel of water be placed in the situation of the vase. It must be evident, that the equiponderancy will be destroyed, since the solid cylinder will be buoyed up by the water. If water be now poured into the hollow cylinder, it will be found that, at the *same* moment *when* the cavity becomes full, the equiponderancy will be restored, and the solid cylinder sunk just below the surface of the water.

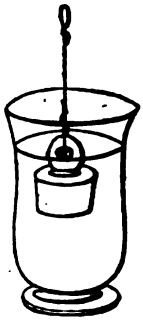
Hence it appears that the resistance which the solid cylinder encounters in sinking in the water, is overcome by the weight of a quantity of water equal to it in bulk. It must be evident, that the same would be true of any other body, and of any other liquid.

Rationale.—When a solid body is introduced into an inelastic solid, on withdrawing it a hole is left, which remains vacant of the solid matter; but no sooner is a body which has been introduced into a liquid withdrawn, than the liquid is found to fill up the space from which it had been removed.

It is evident that the force which liquids thus exert to re-enter any space within them from which they are forcibly excluded, is precisely equal to the weight of a quantity of the liquid commensurate with that space; since, when the space is reoccupied by the liquid, the equilibrium is restored.

Consequently, every body, introduced into a liquid, experiences from it a resistance equal to the weight of a quantity of the liquid, commensurate with the cavity which would be produced, supposing the liquid frozen about the solid mass, split open so as to remove it, and the fragments put together again; and the cavity thus created must obviously be exactly equal to the bulk of the body. It follows, therefore, that the resistance which any body encounters in sinking within a liquid, is equivalent to the weight of a quantity of the liquid, equal in bulk to the body.

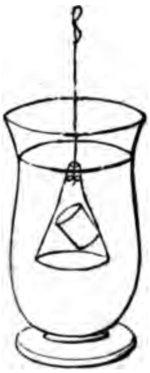
143. *Method of ascertaining the Specific Gravity of a Body heavier than Water.*



Let the glass stopple, represented in the adjoining figure, be the body. First counterpoise the stopple by means of a scale beam and weights, suspending it by a fine metallic wire. Place under the stopple a vessel of pure water, at the temperature of 60°, and lower the beam, so that if the stopple were not resisted by the water, it would be immersed. Add just as much weight as will counteract the resistance which the water opposes to the immersion of the stopple, and render the beam again horizontal. Divide the weight by which the stopple had been previously counterpoised, by the weight thus employed to sink it, and the quotient will be the specific gravity.

Rationale.—The weight requisite to sink the stopple, measures the resistance to its being sunk in the water; and this it has been shown is equal to the weight of a bulk of water equal to that of the stopple. Of course, pursuant to the general rule, it is only necessary to see how often this weight is contained in the weight of the stopple, to ascertain its specific gravity.

144. *Method of ascertaining the Specific Gravity of a Body lighter than Water.*



Let a small glass funnel be suspended from a scale beam, and counterpoised so as to be just below the surface of some water in a vase, as represented in the diagram.

If, while thus situated, a body lighter than water, a small cork for instance, be thrown up under the funnel, the equilibrium will be subverted. Ascertain how much weight will counteract the buoyancy of the cork, add this to its weight, and divide its weight by the sum. The quotient will be the answer.

Rationale.—The force with which the cork rises against the funnel, is equal to the difference between its weight and the weight of the bulk of water which it displaces. Of course, ascertaining the force with which it rises by using just weight enough to counteract it, and adding this weight, so ascertained, to that of the cork, we have the weight of a bulk of water, equal to the bulk of the cork. By this weight, dividing the weight of the cork agreeably to the general rule, the specific gravity of the cork will be found.

145. *Method of ascertaining the Specific Gravity of a Liquid.*

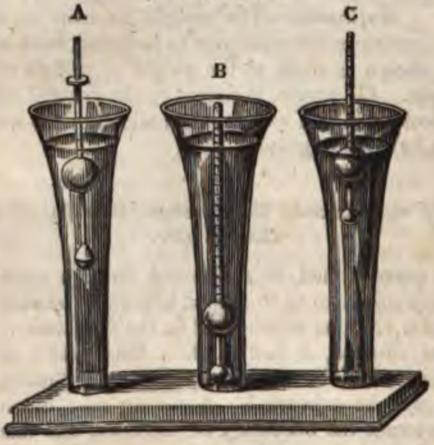
Let the stopple be counterpoised, exactly as in experiment **143**, excepting that it is unnecessary to take any account of the counterpoising weight. Having, in like manner, ascertained how much weight will sink it in the given liquid, divide this by the weight required to sink it in the water. The quotient will be the specific gravity sought.

Rationale.—It has been proved that the resistance to the sinking of a body in any liquid, is precisely equal to the weight of a bulk of the liquid, equal to the bulk of the body. Ascertaining the resistance to the immersion of the same body in different liquids, is, therefore, the same as ascertaining the weights of bulks of those liquids, equal to the bulk of the body, and, of course, to each other. And if one of the liquids be water, dividing by the weight of this the weights of the others, gives their specific gravities.

If the stopple be so proportioned as to lose just one thousand grains by immersion in water, division is unnecessary; as the weight of the liquid will be obtained in grains, which are thousandths by the premises. A piece of metal exactly of the same weight as the stopple, may be employed as its counterpoise.

In these experiments, the liquid should be as near 60° of Fahrenheit's thermometer as possible.

146. *Hydrometers for Alcohol, for Acid, Saline, and other Solutions, and for Vegetable Infusions.*



In these a constant weight is used to a certain extent, and the differences of gravity are estimated by the quantity of the stem immersed. In those instruments of this construction where several weights are employed, the effect is the same as if the stem of the instrument were lengthened as many times as the number of the weights attached to it.

The above engraving represents three hydrometers, A, B, and C, contained in glass vessels. B and C are of glass, and A of metal.

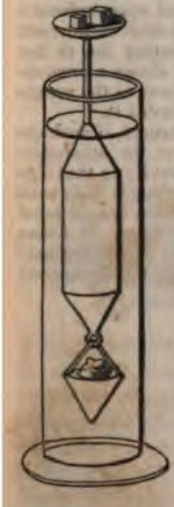
B is intended for liquids heavier than water; C, for those which are lighter. In each, the graduation commences at that point of the stem, to which the instrument sinks in distilled water. It must of course commence at the top of the stem for liquids heavier than water, and at the bottom of the stem for liquids lighter than water. In the latter case, as in that of spirituous liquors or ethers, the strength being greater as the liquid is lighter, more of the stem is immersed in proportion as the liquid is stronger; but the opposite is true in the case of acid and saline solutions, or infusions of vegetable matter; the more the stem emerges from these, the eavier and of course the stronger they are. The instruments are represented as hen swimming in pure water.

A is an hydrometer of a form much used in this country and in England, both r spirit and infusions of vegetable matter. The stem is virtually lengthened by he use of several small weights, which may be slipped on and off at pleasure.

The whole difference between the weight of water and that of the strongest spirit, is equal to about two parts in ten. Of course, an hydrometer for spirit should have on its stem a scale of more than two hundred parts, in order to give the specific gravity of any liquid consisting of water and alcohol. To render such graduation sufficiently discernible, the stem would have to be of very inconvenient length. This is obviated by using different weights. When the heaviest weight is upon the stem, the whole of the stem stands above the surface in distilled water. When the liquid contains enough spirit to allow the whole of the stem to sink in it, while supporting this weight, a lighter weight may be used; and when the stem again would be wholly merged, this last mentioned weight may be exchanged for one still lighter. Supposing the stem graduated into fifty parts, three weights would give fifty degrees each, and the stem unloaded, fifty more. Were the stem graduated into ten parts, nineteen weights would give one hundred and ninety parts, and the stem unloaded, ten more.

An instrument, sometimes called a saccharometer, but precisely similar in principle, is used for infusions of vegetable matter, especially for the wort of brewers and distillers, excepting that the scale begins at the top of the stem, with a line which coincides with the surface of pure water, at sixty degrees Fahrenheit, when the hydrometer is immersed in it. When the infusion is strong enough to support the whole of the stem above its surface, a weight is to be added heavy enough to bring the graduated part of the stem into the liquid. And, in like manner, as the infusion is found stronger, weights still heavier must be added; the process being perfectly analogous to, but the converse of that described in the case of alcohol.

147. *Nicholson's Gravimeter, for ascertaining the Specific Gravity of Solids, either heavier or lighter than Water.*



The accompanying cut is a representation of Nicholson's gravimeter, the construction of which is sufficiently obvious.

On the upper scale of the instrument, whilst floating in water, place any body, the specific gravity of which is to be found—a piece of coin for instance—and add as much weight to the same scale as will sink the gravimeter, until a mark, purposely made in the stem, coincides with the surface of the water. The coin is then to be transferred to the lower scale, and as much weight added to the upper one as compensates this change. This weight is obviously just equivalent to the resistance which the coin encounters in sinking in the water. Let this weight be called A.

In the next place, the body is to be removed from the gravimeter, and as much weight, B, again added to the upper scale, as will cause the mark upon the stem to coincide with the aqueous surface. Of the weight first employed, no account need be taken; but the weight, A, and the weight B, used in the second and third steps of the process, are to be carefully noted, and added together; the sum of A and B is then to be divided by A, the first number noted.. This number, A, represents the weight of a bulk of water, equal in bulk to the coin; while the sum of the numbers, A and B is equivalent to the weight of the coin: since that aggregate weight has been found equivalent to the weight of the coin in sinking the gravimeter.

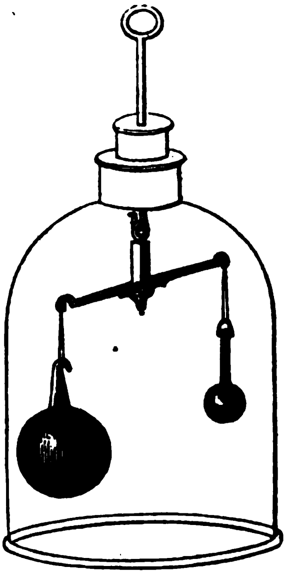
148. *Method of finding the Specific Gravity of a Body lighter than Water by Nicholson's Gravimeter.*

Should the specific gravity of a light body, as a piece of cork for instance, be in question, place it on the upper scale of the gravimeter, load the instrument, so that the mark on the stem may coincide with the surface of the water, as in the case above stated, a leaden disk being previously laid upon the lower scale. The cork being removed, the weight requisite to compensate its absence, gives the weight of the cork. This weight, being added to that which will compensate its buoyancy when immersed in water by being placed beneath the leaden dish lower scale, gives the weight of a quantity of water equal in bulk to th Hence, if the number of grains representing the weight of the cork be div that representing the weight of its bulk of water, the quotient will be the gravity, which, in this case, must be expressed in a decimal fraction, as it than unity.

Of the Influence of the Air on the apparent Weight of Bodies.

A pleasant illustration of the loss of weight, and consequent inaccuracy att on the ordinary process of weighing, as conducted in the air, is afforded by paratus and process described in this article.

149. *A Pound of Feathers heavier than a Pound of Lead.*



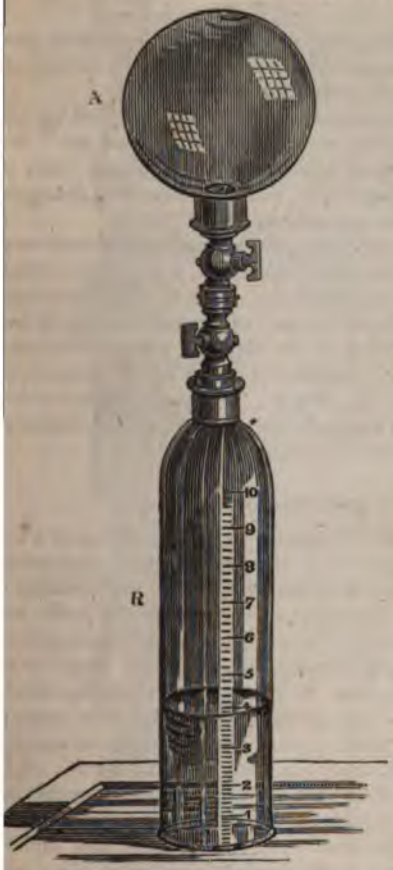
If two bodies, one of which is more bull the other, be found equiponderant in th nary process of weighing by a balance, th body is the heavier.

Let the bodies in question be those rep ed within the receiver of an air-pump, annexed figure. On withdrawing the means of the pump, it will be found t larger body preponderates, though pre counterpoised with accuracy.

Rationale.—It appears from a precedin tration, 146, that, when any body is surr by a fluid, it is buoyed up with a force in tion to the weight of the fluid, and the q displaced by the body. Of course, th space it occupies in proportion to its wei more will its weight be counteracted. case of the two bodies rendered equipond air, the weight of the larger is most count by the air. Hence, on exhausting the a the receiver, the larger body shows a pr rancy over the other, equivalent to the s support which the air had afforded it.

A similar result may be obtained, if hy be substituted in the receiver for atmo air; because, as its specific gravity to tha air is only as 1 to 14 nearly, each body lose 13-14ths of the support which the air forded; but the larger body, having received more, would lose more. It that the common saying, that " a pound of feathers is as heavy as a pound o falls short of the truth; as they would really prove heavier were the air re

150. *Method of ascertaining the Specific Gravity of Gaseous Substances.*



Suppose the globe, A, represented in the adjoining figure, to be removed from the receiver, R, and exhausted during a temporary attachment to an air-pump, by means of a screw with which the globe is furnished, and which serves also to fasten it to the receiver, as represented in the figure. Being preserved in this state of exhaustion by closing the cock, let it be suspended from a scale beam, and accurately counterpoised, as in a former experiment, 62. In that experiment, after the globe was counterpoised, air was admitted and caused it to preponderate decidedly. If in lieu of admitting air, the globe be restored to the situation in which it appears in this figure, so as to be filled with hydrogen from the receiver, R, and afterwards once more suspended from the beam, instead of preponderating decidedly as when air was allowed to enter, the additional weight acquired by it in consequence of the admission of the hydrogen, will scarcely be rendered perceptible. Sup- ng, however, that the additional weight thus acquired were detected, also the weight gained by the admission of exactly the same bulk of at- pheric air, after a similar exhaustion of the globe, the weights of equal mes of hydrogen and air would be represented by the weights thus as- ained. The specific gravity of atmospheric air is the unit, in multiples fractions of which the specific gravities of the gases are expressed. ce the weight of a given bulk of hydrogen, divided by the weight of equal bulk of air, gives the specific gravity of hydrogen. By a similar cess, the specific gravity of any other gas may be ascertained.

table of the specific gravity of the gases will be given in the Appen-

SECTION IV.

OF THE MODE OF COLLECTING AND PRESERVING G.

The art of collecting, preserving, measuring, and distinguishing g substances, has been called *pneumatic chemistry*. It is a branch science which has existed for little more than half a century.

All gases were considered as common air variously modified by i ties, until Dr. Black ascertained the nature of carbonic acid gas.] by this discovery, oxygen, nitrogen, hydrogen, chlorine, and many substances susceptible of the gaseous state, were discovered or disting by Scheele, Priestley, Cavendish, and others.

Cisterns filled with water or mercury, called *hydro-pneumatic* o *curio-pneumatic*, according to the liquid employed, are used for coll gases. The vessels intended to contain the gas are filled with wa mercury, and placed, in an inverted position, on a shelf, or part of t tern, situated just below the surface of the liquid. As their orific not raised above the surface, they remain full of the liquid, in conse of the pressure of the atmosphere. See 65. Any gas emitted unc mouth of a vessel, so filled and situated, rises to the top and displac contained liquid.

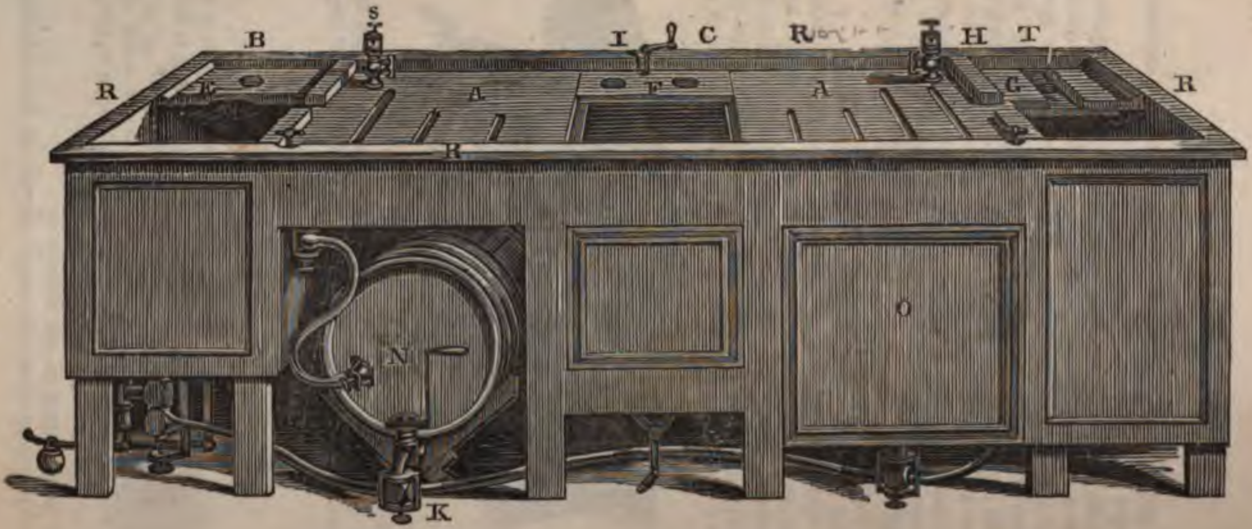
151. *Hydro-pneumatic Cistern.*

In the Appendix will be found an engraving and description of a l pneumatic cistern, which I employed in the experimental illustrati my lectures for more than ten years; and which I should probabl tinue to use now, had not the command of water from the public ' put it into my power to dispense with the mechanism for keeping the at a proper level. As I am now situated, any deficit of water is supplied from the pipes known here as the hydrant pipes, by whi city is supplied with water; and any excess is carried off by a wast

A A, (see opposite engraving) is a water-tight platform, surroun a wooden rim, R R R R, rising above it about an inch and a half. B are three wells or cavities, each in the form of a hollow parallel with all of which the cavity bounded by the rim communicates; s when supplied with water to the level of the waste pipe, this liqui the wells, and covers the platform to the depth of about ¾ths of an ir

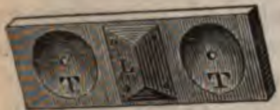
E, F, G, are shelves, which severally move in grooves over the so that they may be placed in the most convenient position. Unde a waste pipe. At I, is a winch which serves to let in water from the reservoirs. K, is a pipe for emptying the wells and casks, with which, by means of cocks, it may be made to communicate when site. N, is a cask which acts as a gas holder, having a commun with the cistern for letting in water from that source; the orifices controlled by valves. By means of a pipe proceeding from its vert gas holder communicates with a pipe or cock, at s, furnished with lows screw. To this, flexible leaden pipes may be attached, for tr ring gas either from the gas holder to a bell glass, or from a bell g the gas holder. When a communication is established between th ties, either of these offices may be performed, accordingly as the pr within the holder is made greater or less than that of the atmosphe will be greater when the valve for the admission of water is opened

Hydro-pneumatic Cistern.



for letting it out being shut; and less when these circumstances are reversed.

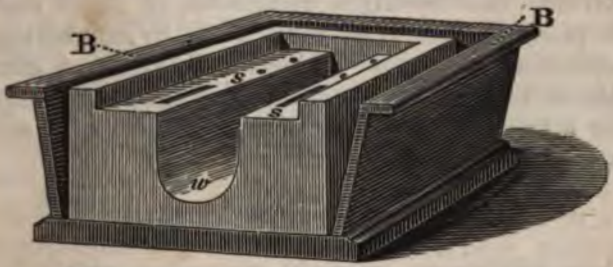
Another cask with pipes and cocks, similar to that represented in the engraving, is concealed by the pannel, O.



This cut affords a view of the lower side of the sliding shelf, in the wood of which will be seen two excavations, T, T, converging into two holes. This shelf is loaded with an ingot of lead at L, to prevent it from floating in the water of the cistern.

152. *Mercurio-pneumatic Cistern.*

The following figure represents the mercurial cistern used in my laboratory. The front is supposed to be removed, that the inside may be exposed to view.



B B, is a wooden box, which encloses the reservoir so as to catch any of the metal which may be propelled over the margin of the cistern. This box is bottomed upon stout pieces of scantling, tenanted together and grooved so as to conduct the mercury towards one corner, where there is a spout to allow it to escape into a vessel, situated so as to receive it. The cistern itself is made out of a solid block of white marble. It is 27 inches long, 24 wide, and 10 deep.

The ledges, S S, answer for the same purposes as the shelves in the hydro-pneumatic cistern described in the preceding article. The excavation, *w*, constitutes the well. In this well vessels are filled with mercury, in order to be inverted and placed while full on the ledges. There are some round holes in the marble for introducing upright wires to hold tubes or eudiometers; also some oblong mortices for allowing the ends of tubes, duly recurved, to enter under the edges of vessels to be filled with gas, and in cases of rapid absorption, to afford a passage for the mercury into vessels, from which it might otherwise be excluded in consequence of their close contact with the marble of the reservoir.

To fill this reservoir requires nearly 600 pounds of mercury.

INDIVIDUAL INORGANIC SUBSTANCES.

[These substances are either simple or compound. The simple substances will be first treated of, according to a classification to be explained presently; and under the head of each, the principal binary compounds will be introduced. The more complex compounds, called salts, will afterwards be considered under a separate head.]

SIMPLE INORGANIC SUBSTANCES.

[The simple substances are fifty-four in number. According to the classification of Dr. Hare, they are primarily divided into *basacigen substances*, or those elements which produce both acids and bases by combining with the remaining elements; and *radicals*, or those elements capable of forming with a basacigen substance, either an acid or a base, or both, and which do not form acids or bases with each other.]

OF BASACIGEN SUBSTANCES.

[These substances are eight in number, viz:

Oxygen,
Chlorine,
Bromine,
Iodine,
Fluorine,
Sulphur,
Selenium,
Tellurium.[*]

They will be treated of, in the order in which they have been named, in the eight following sections.]

---

[*] Of these substances *chlorine*, *bromine*, *iodine* and *fluorine* are classed by Berzelius under the name of *halogen bodies*, or generators of salts; while *oxygen*, *sulphur*, *selenium*, and *tellurium* are classed together under the name of *amphigen bodies*, or both producers; meaning that they are productive both of acids and bases. For reasons stated in a letter to Professor Silliman, which will be found in the Appendix, I object to this classification. It appears to me, from the facts stated by Berzelius, coupled with his own practice, that the bodies of both of his classes are productive of acids and bases. Influenced by this impression, I have associated them as above in one class, under the appellation of *basacigen substances*. In honour of Berzelius I shall, however, retain the terms *halogen* and *amphigen*, in order to designate the elements which he has distinguished by those names. It may be proper to add that we owe to Berzelius himself the idea that any other substance besides oxygen could form acids and bases capable of uniting to form salts. Our knowledge of the existence of this faculty in three of his amphigen elements, sulphur, selenium and tellurium, is, I believe, entirely due to his investigations. If chemists, myself among others, who consider his double salts as consisting of acids and bases, are in the right, it is to the light afforded by his brilliant discoveries that we owe the ability to pursue the true path.

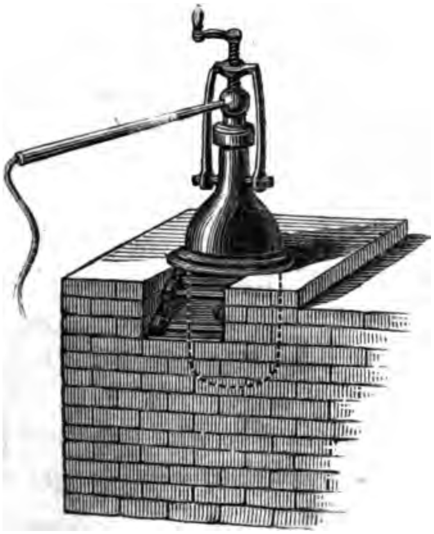
SECTION I.

OF OXYGEN.

In the gaseous state, oxygen forms one-fifth of the atnosphere in bulk; and as a constituent of water in the atio of eight parts in nine, it pervades every part of the reation where that important compound is to be found. t exists in that congeries of oxidized matter which we all earth, and is a principal and universal constituent of nimal and vegetable matter. Its combinations with meals and various other combustibles are of the highest mportance in the arts. It was called oxygen under the rroneous impression of its being the sole acidifying priniple, from the Greek ὀξυς acid, and γινομαι to generate.

Preparation.—It can only be isolated in the form of a as. It is yielded by red lead, nitre, or black oxide of nanganese, when exposed to a bright red heat in an iron ottle. There are various other means of obtaining oxyen gas. It is generally supposed that, in order to obtain t in a high degree of purity, chlorate of potash must be mployed; but I have found the first portions of the gas rom nitre quite pure; and Dr. Thomson alleges that this alt, by exposure to a carefully regulated heat, parts with ne-fifth of the oxygen of its acid in a state of purity; or n other words, it gives up an atom of oxygen for every tom of the salt, which is equal to 8 parts in 102 parts, r rather less than one-twelfth.

153. *Apparatus for obtaining Oxygen upon a large Scale.*



As nearly as much time and trouble are expended in conducting a chemical process on a small scale as upon a large one; and as in my experiments I consume large quantities of oxygen gas, I have lately employed the cast iron alembic represented in the preceding figure, for the purpose of obtaining the gas from 12 or 15 pounds of nitre. When in operation, it is made to occupy a suitable cavity in a brick stack. The neck is so formed as to receive a large hollow knob of iron, from which a gun barrel proceeds at right angles. This knob is secured by a gallows screw, embracing the arms cast with the alembic. The juncture is to be luted with clay, added dry to a saturated solution of borax. To the orifice of the gun barrel, a flexible leaden pipe is attached, by which the gas is conveyed to the gas holders or gasometer.

Care is taken to use no more fire than will bring over the gas, and the operation is arrested as soon as the impurity exceeds 20 per cent. By attending to these precautions, the gas is of better quality; the first portion being nearly pure, and the alembic is less corroded. Besides, the nitrate, being converted into nitrite of potash, produces, by deflagration with charcoal, a tolerably pure carbonate of potash.

Properties of Oxygen.—The specific gravity of this gas, atmospheric air being 1., is 1.1024. One hundred cubic inches of it weigh 34.1872 grains. In refracting light, oxygen is inferior in power to any of the other gases.

It is insipid, inodorous, colourless, and transparent. It is but slightly absorbed by water, does not differ from common air in appearance, but is somewhat heavier, and supports life and combustion more actively. Under a bell glass filled with oxygen gas, an animal lives and a candle burns thrice as long, as when similarly situated with the same quantity of common air.

Oxygen gas is supposed to consist of oxygen rendered aëriform by caloric.

The equivalent of oxygen is 8, hydrogen being unity.

154. *Experimental Illustrations of the Properties of Oxygen Gas.*

Several cylindrical glass vessels of an appropriate shape being filled with the gas over one of the shelves of the pneumatic apparatus, the following illustrations of the energy of oxygen gas in supporting combustion are afforded.

Let a stout wire be made, at one of its ends, to embrace a lighted candle, so that it may be conveniently lowered into the bell while replete with oxygen. It will be found that, if the flame be extinguished, and the candle lowered into the gas while the snuff remains red-hot, the inflammation will be renewed with great energy.

The vessel being replenished with the gas, the flame of a piece of caoutchouc, which, after being ignited, is lowered into it, acquires a dazzling brightness.

Let Homberg's pyrophorus, or preferably such as I have contrived to obtain from Prussian blue, be thrown into the gas. The pyrophorus, in descending through the gas, taking fire spontaneously, appears like an igneous shower.

Charcoal powder, or filings of iron or steel, being made red-hot in a crucible, and then projected into oxygen in a receiver, a vivid extrication of heat and light ensues.

If the hydrostatic blowpipe be supplied with oxygen, and be made to act upon a lamp flame, an intense heat will be excited. See article 119.

An iron wire, being heated in the flame thus excited by oxygen, takes fire, and continues to burn splendidly, although the lamp be removed.

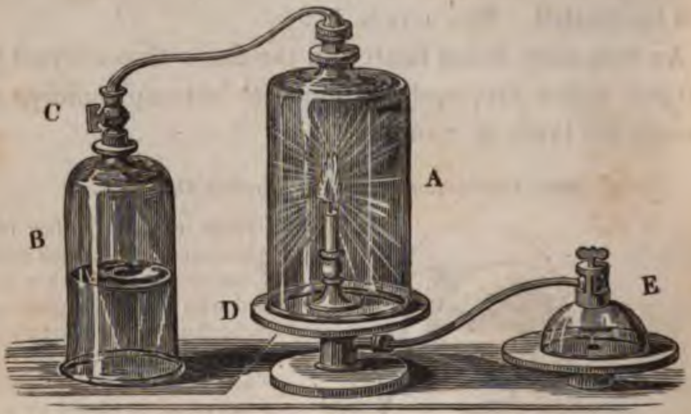
155. *Combustion of Iron or Steel in Oxygen.*

Place over the orifice of a pipe communicating with a cock of one of the air holders supplied with oxygen, a glass vessel, such as is usually employed to shelter candles from currents of air. Let the upper opening of the vessel be closed by a lid with a central circular aperture, as represented in the engraving. Leaving this aperture open, by turning the key of the cock, allow the gas to rise into the vessel, from the holder. Next apply a taper to the aperture, and as soon as it indicates, by an increased brilliancy of combustion, that oxygen has taken the place of the air previously in the vessel, cover the aperture. In the next place, attach a small piece of spunk to one end of a watch spring, or of a spiral wire as in the figure. Ignite the spunk, and removing the cover, plunge the end of the spring associated with the spunk into the gas. The access of the oxygen causes the spunk to be ignited so vividly, that the spring takes fire and burns with great splendour, forming a brilliant liquid globule, which scintillates beautifully. This globule is so intensely hot, that sometimes, on falling, it cannot immediately sink into the water, but leaps about on the surface, in consequence of the steam which it causes the water to emit. If it be thrown against the glass of the containing vessel, it usually fuses it without causing a fracture, and has been known to pass through the glass, producing a perforation without any other injury.

The phenomena last mentioned are more likely to be produced when an iron wire is used in this experiment, than when a steel spring is employed.

156. *Necessity of Oxygen to a Candle Flame demonstrated.*

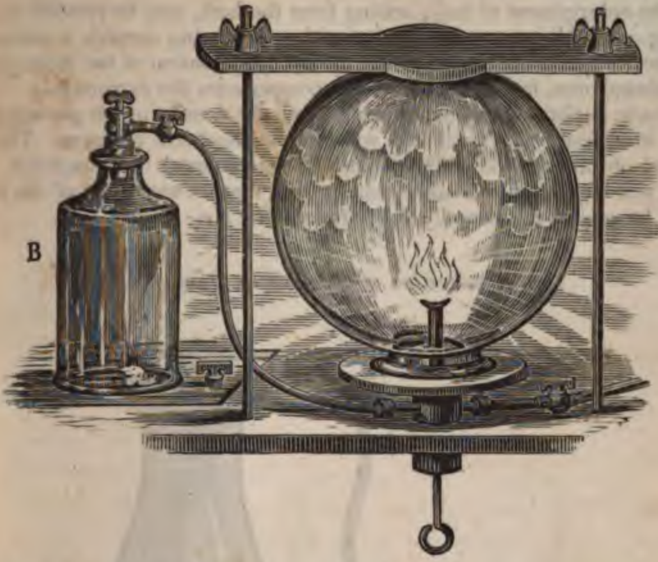
A candle will burn only for a limited time in a limited supply of air; it will not burn in vacuo, but burns brilliantly in oxygen gas, and much longer than in a like quantity of air.



Let there be two bell glasses, A and B, communicating with each other by a flexible leaden pipe, a cock intervening at C. Suppose A to be placed over a lighted candle on the plate, D, which communicates with an air pump plate as represented at E. It will be found that the candle will gradually burn more dimly, and will at last go out, if no supply of fresh air be allowed to enter the containing bell. If on repeating the experiment, the air be withdrawn by means of the pump, the candle is rapidly extinguished. It is thus demonstrated that a candle will not burn in vacuo, and that it can burn only for a limited time, in a limited portion of atmospheric air.

If, while the bell, A, is exhausted, the cock at C be opened, communicating with the receiver, B, filled with oxygen over the pneumatic cistern, the water will rise into and fill the receiver, while the gas will be transferred to the bell. By means of the galvano-ignition apparatus described in article **111**, the candle may be again lighted in the oxygen, when it will burn splendidly.

157. *Combustion of Phosphorus in Oxygen Gas.*



A brass plate, which answers as an extra air pump plate, and is of course ground into a plane as true as possible, is supported on a hollow cylinder of the same metal. Concentric with the axis of this cylinder, and passing up through it, so as to reach about three inches above the plate, there is a tube of about three-fourths of an inch in diameter, open below, but closed above by a concave copper disk to which it is hard soldered. The tube is fastened into the cylinder by a brass screw plug, in the centre of which the tube is made air-tight by solder. Hence although the bore of the tube is accessible from below, so far up as the concave copper disk which surmounts it, no air can pass through it or through the cylinder.

An adequate quantity of phosphorus being placed upon the copper disk, a glass globe is placed over it upon the plate; and by causing one of the pipes which are attached laterally to the cylinder to communicate with an air pump, the globe is exhausted. By means of the other pipe, a due quantity of oxygen gas is then let in from the bell glass, B, to which this pipe is annexed. The apparatus being thus prepared, the end of an iron rod previously reddened in the fire, is passed through the bore of the tube so as to touch the copper disk which holds the phosphorus. The most vivid ignition ensues. The light has at first a dazzling beauty, but is soon "shorn of its beams" by the dense white fumes of phosphoric acid, which the combustion evolves. Hence an effulgence, approaching to solar brilliancy, soon yields to a milder illumination like that of the moon, which is rendered more pleasing by the contrast.

The globes with which I am accustomed to perform this experiment, contain from 12 to 15 gallons. It is better that the gas in the globe should be in some degree rarefied; otherwise the expansion at first excites a considerable effort in the air to escape. In one instance, a small piece of iron wire, with which the phosphorus was tied, took fire, and, falling in a burning globule on the neck of the globe, caused it to fly into pieces.

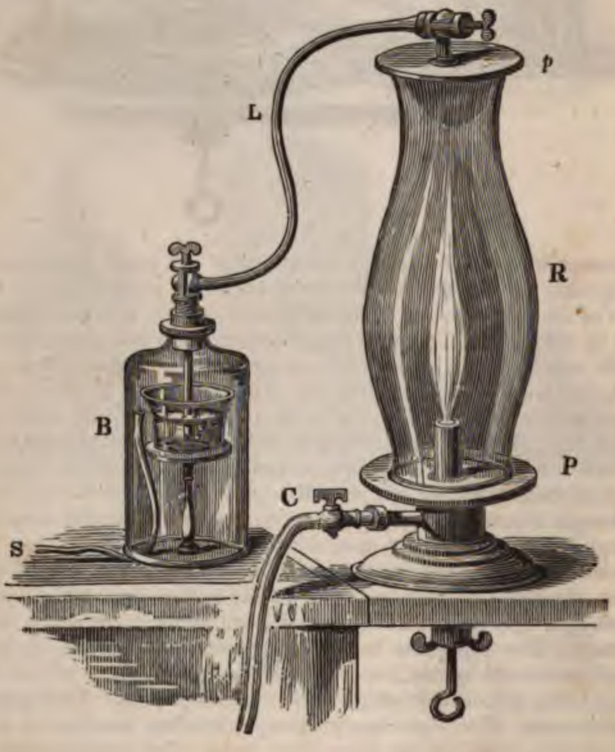
At the same time the expansion was sufficient to throw the pieces to
tance of four or five feet apart.

The enlargement of bulk, arising from the heat, may be provided f
a bag or bladder, a communication with which being opened, a porti
the heated gas is enabled to retire, till the condensation of the oxygen
the phosphorus, into phosphoric acid, compensates the expansion.

I have performed this experiment, when the density of the gas was
half less than if in equilibrio with the atmospheric pressure. Th
course obviated the possibility of any ill consequences from expansion

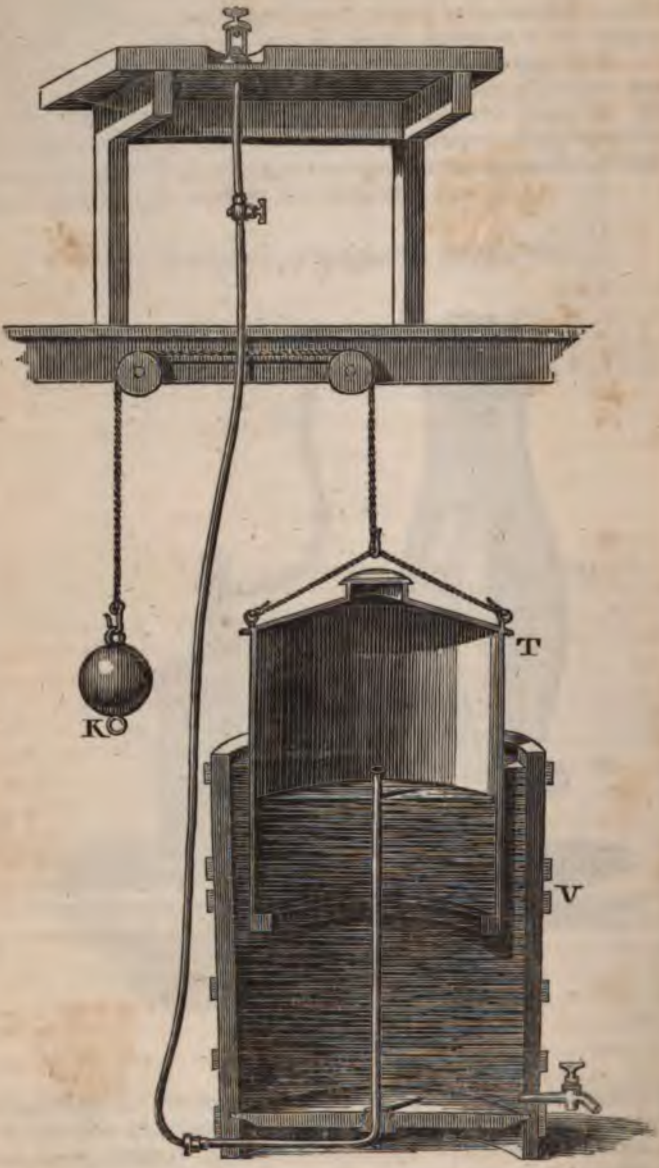
It will be shown in a subsequent article, that an apparatus of this
may be applied to the analysis of atmospheric air.

158. *Combustion of Sulphur in Oxygen Gas.*



Supposing the junctures made by the plates, P *p*, with the receive
to be air-tight, and that there is a communication between it and the
glass, B, by means of a flexible leaden pipe, L, it must follow that, w
ever the suction pump, from which the recurved pipe, S, terminating
in the bell, proceeds, is made to act, the air in B being rarefied, that
will force its way through L, and the liquid in the vase upon the st
It must also be evident that, if the pipe and cock, C, communicate, on
side with the receiver, on the other with a reservoir of oxygen, this

Large Gasometer for Oxygen.



will be impelled into the receiver, as soon as the cock is opened, in order o restore the equilibrium destroyed by the suction pump.

The plate, P, with its supporting hollow brass cylinder, has been already lescribed in the preceding article. The tube, surmounted by the disk, sed in the combustion of phosphorus, is removed, and in its place a piece f a gun barrel is, in like manner, fastened, so that the butt-end may ccupy the axis of the cylinder. The touch-hole being closed, a perforaion, similar in size, is drilled in the end of the barrel, at the point from which the flame is represented as proceeding in the figure. In order to roduce this jet of vaporized sulphur, some cotton wick is wound about the nd of a rod, and tied on it. The tuft, thus made, is soaked in melted rimstone. The gun barrel, during a temporary removal, is heated red-ot at the butt-end, where it is perforated. Being screwed into its place gain, the rod, armed with the cotton and sulphur, is pushed up into the ore of the barrel. By the heat of the iron, the sulphur is converted into a hot vapour, which, issuing in a jet from the perforation, enters into combustion with the oxygen in the receiver.

In consequence of the rarefaction of the air in the bell, B, by the suction pump, the fumes of the burning vaporized sulphur are drawn through the water in the vase upon the stand, in which, consequently, a mixed solution of sulphuric and sulphurous acids is produced.

159. *Large Gasometer for Oxygen.*

The opposite engraving represents a section of my gasometer for oxygen, which is capable of holding between five and six cubic feet of gas. It is represented as it was situated, when the drawing was made, in the cellar under my lecture room. It is now placed in the lecture room in front of my table, near one end. The wooden tub, V, is necessarily kept nearly full of water. The cylindrical vessel, T, of tinned iron, is inverted in the tub, and suspended and counterpoised by the rope and weight, in such manner as to receive any gas which may proceed from the orifice of the pipe in its axis. This pipe, passing by means of a water-tight juncture through the bottom of the tub, is extended to a cock fixed in a cavity made in the plank forming the rim of the pneumatic cistern. Hence by means of this cock, and a leaden pipe soldered to a brass knob, properly perforated, a communication may be established between the cavity of the gasometer and any other vessel, for the purpose either of introducing or withdrawing gas. In filling this gasometer, the copper vessel and bell glass, used in obtaining nitrous oxide, may be employed advantageously; or the counter-weight being made heavier than the vessel by appending additional weight to the ring, K, the gas may be sucked in from a bell glass, situated over the pneumatic cistern, as fast as it enters the bell from the generating apparatus.

As the gas displaces the water from the cavity of the vessel, T, the latter becomes more buoyant and consequently rises. When any gas is withdrawn or expelled, the water resumes its place, and the vessel sinks.

Gasometers which contain 40 or 50,000 cubic feet have been constructed upon this principle for holding the gas from oil or coal. They are usually hollow parallelopipeds. The upper vessel is generally made of varnished sheet iron, the lower one of brick-work or cast iron. The space within the lower vessel, which is included by the upper one when down, is filled up, so as to lessen the quantity of water required. (See article on carburetted hydrogen.)

SECTION II.

OF CHLORINE.

As a gas chlorine exists only by artificial means; but as an ingredient in marine salt, in the proportion of three-fifths, it constitutes nearly one-fiftieth of the matter in the ocean, and is widely disseminated throughout the land as well as the sea. It is also an ingredient in some of the most active agents used in chemistry or medicine. It was discovered by Scheele, and called by him dephlogisticated marine acid. It afterwards received the name of oxygenated muriatic acid, or oxymuriatic acid, from Lavoisier and the chemists who adopted his nomenclature. Its present name was given by Sir H. Davy, from χλωρος, green, because its colour is greenish.

Preparation.—It is obtained by heating in a glass or leaden retort or alembic, three parts of black oxide of manganese, with four parts of muriatic acid; or the same quantity of this oxide, with eight parts of common salt, four parts of sulphuric acid, and four parts of water.

Being a gas, it must be received over the hydro-pneumatic cistern in bell glasses or bottles. As much of it is absorbed if it remain long in contact with the water, I generally employ glass bottles with air-tight stopples, in order that they may be removed from the water as soon as filled.

Berzelius alleges that if the water employed be saturated with salt, there is less absorption.

Jars or bottles may be filled with chlorine gas, by means of a tube or retort beak, as in fig. 1, of the following engraving, reaching from the generating vessel to the bottom of that into which it is to be introduced. The air is displaced by the chlorine, in consequence of its superior gravity, without any admixture ensuing adequate to interfere with the exhibition of its characteristic properties.

When substances which take fire in the gas are to be introduced, it is expedient that a communication should exist with the inside of a bladder attached as in the following figures, which represent apparatus, of which fig. 1 may be used for the combustion of metallic powders, fig. 2 for that of phosphorus, introduced by means of the ladle L.

Fig. 1.

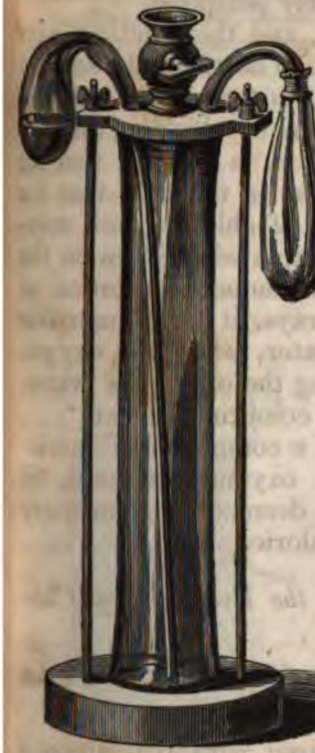
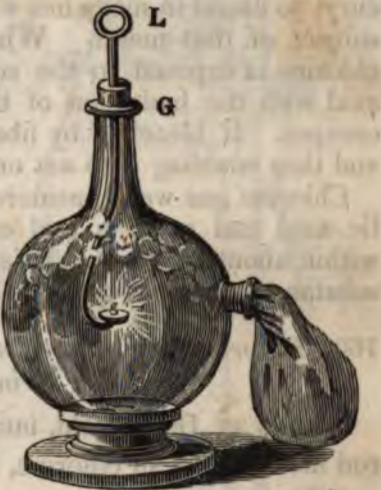


Fig. 2.



Properties.—When pure and dry, chlorine is a permanent gas of a greenish-yellow colour. Its weight to that of common air, is nearly as two and a half to one. Even when existing in the air in very small proportion, it is intolerable to the organs of respiration, and to respire it pure, would quickly produce fatal consequences.

Mr. Faraday has shown that, under great pressure, chlorine becomes a liquid. It will remain liquid some instants after all pressure is removed, in consequence of the great cold produced by its evaporation.

That species of chemical action which is attended with the phenomena of combustion, is supported by this gas with great energy. It combines directly with every combustible except carbon. It has a curious property, first noticed by me I believe, of exciting a sensation of warmth; though a thermometer, immersed in it at the same time, does not indicate that its temperature is greater than that

of the adjoining medium. Heat is probably produced l
a reaction with the matter insensibly perspired.

Chlorine is absorbed by water, and the solution ac
powerfully on metals. It appears to be the only solve
of gold. At the temperature of 40° it forms with water
solid hydrate, consisting of 1 atom of chlorine, and 1
atoms of water. Silver, in solution, is the best test f
chlorine; and, reciprocally, chlorine is the best test f
dissolved silver. The compounds of chlorine with me
cury, so useful in medicine, will be treated of when on th
subject of that metal. When the aqueous solution
chlorine is exposed to the solar rays, it forms muriati
acid with the hydrogen of the water, while the oxyge
escapes. It bleaches by liberating the oxygen of wate
and thus enabling it to act on the colouring matter.

Chlorine gas was considered as a compound of muri
tic acid and oxygen, and called oxymuriatic acid, ti
within about 26 years. It is now deemed an elementa
substance, rendered gaseous by caloric.

160. *Experimental Illustrations of the Properties of Chl rine.*

Leaves of Dutch gold, introduced by means of a gla
rod into a bottle of chlorine, take fire.

Effect upon the fingers compared with that upon
thermometer.

An infusion of litmus whitened in falling through th
gas.

A lighted candle introduced.

161. *Combustion of Antimony in Chlorine.*

When an air pump is at hand, the following apparatus may be us
for the combustion of powdered antimony. It consists of a large j
closed air-tight, and supported in the screw rod and plate frame describ
in article 100, page 94.

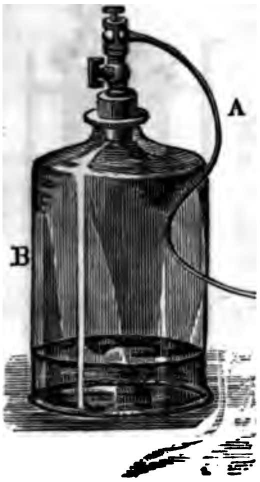
By means of one of the flexible pipes and cocks with which the appar
tus is furnished, communication may be made with an air pump, and wi
a large vessel, A B, containing chlorine.

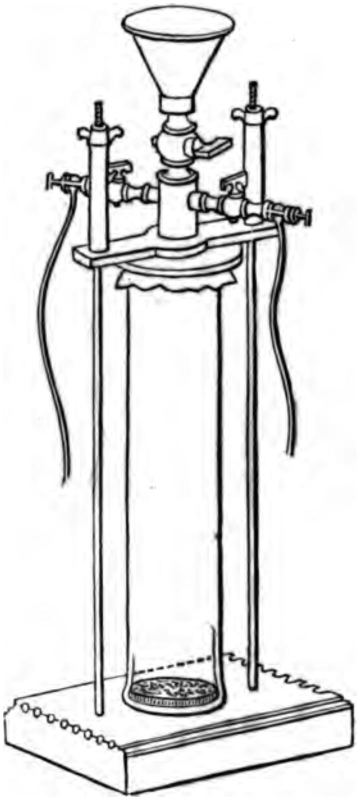
Into the centre of the lid a cock is fastened, the key of which, inste
of being perforated as usual, is drilled only half through, so as to produ
an excavation capable of holding a thimbleful of powder.

The cavity in the key of the cock is charged with pulverized antimo
which, on turning the key half round, falls through the chlorine, and as
falls assumes the appearance of a shower of fire. The cock being, fro

its construction, always closed, and the junctures being tight, the spectators are protected from the noxious fumes.

In this experiment, the chlorine forms with the antimony, a compound which has less capacity for caloric and light than its ingredients have separately. Hence, by their combination, the phenomena of combustion are produced. The product of the combustion is the perchloride.





162. *Combustion of Metallic Leaf* in Chlorine.*

The apparatus used in this experiment (See fig. 1,) differs but little from the one above represented, being the same as that described in article 100, page 94, excepting the funnel, which is unnecessary in this case.

Into the lower end of the cock a rod of iron is screwed fast. This rod is of such dimensions as to extend from the top to the bottom of the receiver, and is supported within it, so as to be in its axis or every where equidistant from the surface.

Before fastening the plate into the situation in which it is represented in the figure, it must be lifted in order to attach the leaf metal to the rod with the aid of gum arabic.

The arrangements being so far completed, the cylindrical receiver having been exhausted by means of the air pump, the cock, regulating the communication with that instrument, is to be closed, and the other which controls the entrance of the gas is to be opened. By these means the leaves burn splendidly, being simultaneously enveloped in an atmosphere of chlorine, which rushes in to supply the vacuum caused by the air pump.

---

* The metal usually employed is the Dutch gold leaf of the shops, an alloy principally of copper and zinc.

Another method of performing this experiment is illustrated by fig. 2.

Fig. 1.

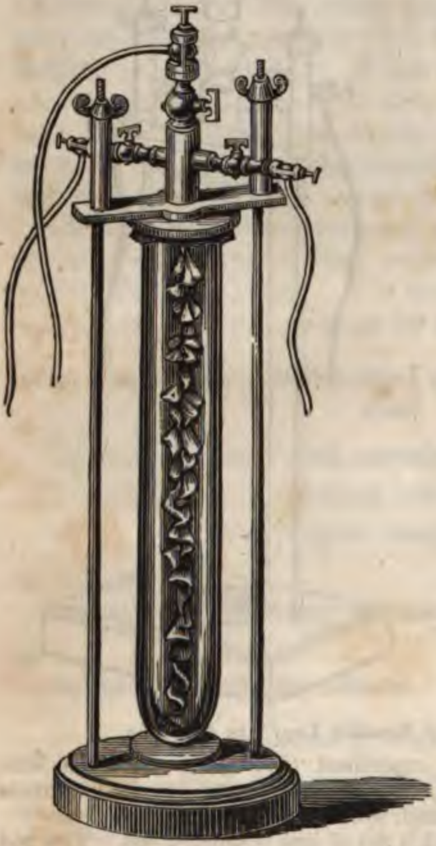
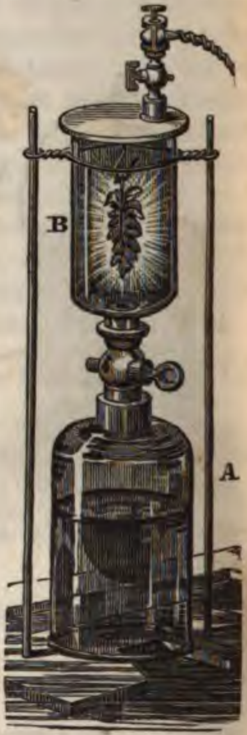


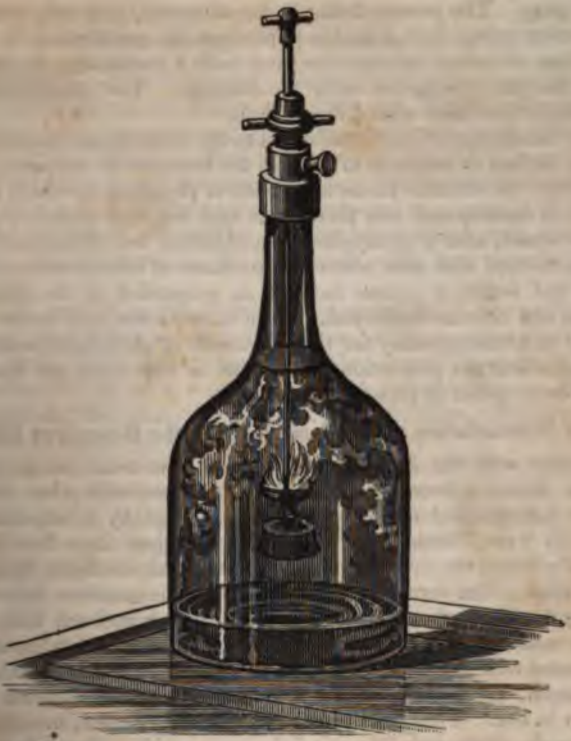
Fig. 2.



The metallic leaves being suspended from the plate which closes the bell, B, and this bell being exhausted of air by means of the pump, chlorine is suddenly admitted into it by the glass cock from the bell glass, A, previously supplied with the gas.

163. *Spontaneous Combustion of Phosphorus in Chlorine.*

The following figure is intended to convey an idea of the spontaneous inflammation of phosphorus in chlorine, by means of an apparatus which



enables the lecturer to perform the experiment without exposing spectators to the fumes.

Let there be a cylindrical glass vessel, (see the above figure) eight or nine inches in diameter, and about a foot in height, with a neck about four inches high, and one and a half inches in bore; the whole resembling a large decanter without a bottom. About the orifice of the neck, let there be cemented, air-tight, a brass cap, surmounted by a stuffing box, and having on one side a hole communicating with the cavity of the neck. This aperture must be furnished with a thumb screw, by which it may be opened or closed at pleasure. Through the stuffing box a copper rod passes, at the lower end of which a glass or leaden stopple is so affixed, as to close the lower part of the neck, into which it is ground to fit air-tight. Over this stopple, a cup of copper is soldered, so as to be concentric with the rod. The rod terminates above in a handle. Within the cup, let ten or fifteen grains of phosphorus be placed. This is easily effected when the cup and plug are depressed into the lower part of the cavity of the vessel, by a suitable movement of the sliding rod. In the next place draw up the cup and plug into the neck, so as nearly but not entirely to close it, and sink the vessel into the water of the pneumatic cistern until all the air below the neck is expelled through the hole in the side of it, which is then to be closed by means of the screw, and the plug twisted and drawn into its place, so as to be air-tight. After filling the body of the vessel thus with water place it upon the shelf of the cistern. Chlorine may now be allowed to occupy three-fourths of the space within the vessel below the plug. The process being so far advanced, it is only necessary, at the moment when it is desirable to produce the combustion, to depress the plug, and of course the cup associated with it containing the phosphorus, into the cavity supplied with the chlorine. The phosphorus soon burns actively, although with a feeble light.

The increased temperature consequent to the combustion, causes the gas to expand, but not so much as to become too bulky to be retained.

In this case the chlorine forms a chloride of phosphorus, which meeting with water is decomposed into phosphoric and muriatic acids. By transferring the vessel, after it is supplied with chlorine, to a clean porcelain or glass dish, covered with pure water, the products of this combustion might be saved, and would of course increase in proportion to the quantity of phosphorus and chlorine employed. On a larger scale, this process might be resorted to advantageously for the generation of phosphoric acid, which is produced when the proportion of chlorine is sufficient; say four cubic inches for every grain of phosphorus.

Of the Nomenclature of the Compounds of the Basacigen Class.

Consistently with the French nomenclature, the combinations formed by oxygen, chlorine, bromine, iodine, and fluorine, with other elements, have been distinguished as *acids*, or characterized by a termination in "*ide*," or in "*ure*," which last monosyllable, when there has been no intention of altering the meaning, has, by the British chemists, been translated into *uret*. The termination in *ide*, which is common to both languages, is, by Thenard, and other eminent French authors, restricted to the binary compounds of oxygen which are not acid. Analogous compounds formed with the *halogen* elements, chlorine, bromine, iodine, fluorine, cyanogen, &c., have by the same writer been designated by the termination in *ure*. Thus we have in his work, chlorures, bromures, iodures, fluorures, cyanures. Some of the most eminent chemists in Great Britain have distinguished the elements called halogen by Berzelius, together with oxygen, as supporters of combustion, and have designated the binary compounds made with them, when not acid, by the same termination as the analogous compounds of oxygen. Accordingly in their writings, instead of the names above mentioned, we have chlorides, bromides, iodides, fluorides. In Henry's Chemistry, cyanure is represented by cyanide, in Thomson's, by cyanodide, and in Brande's and Turner's by cyanuret. I shall follow the practice of the British chemists in the case of the four first mentioned compounds, extending it to the compounds of cyanogen, as Henry has done.

These rules of nomenclature will be considered as extending to all the basacigen class. Of course the compounds of sulphur, selenium and tellurium, when not acid, will be designated by appellations terminating in *ide*. In lieu, therefore, of ***sulphuret***, ***selenuret*** and ***telluret***, I shall employ the words, ***sulphide***, ***selenide*** and ***telluride***.

COMPOUNDS OF CHLORINE WITH OXYGEN.

1 atom or 1 volume of chlorine equivalent 36, forms	With 1 atom, or ½ volume of oxygen, euchlorine or the protoxide of chlorine, - - -	44
	With 3 atoms, or 1½ volumes of oxygen, chlorous acid, - - - - - - -	60
	With 5 atoms, or 2½ volumes of oxygen, chloric acid, - - - - - - -	76
	With 7 atoms, or 3½ volumes of oxygen, oxychloric acid, - - - - - - -	92

Of Euchlorine, or Protoxide of Chlorine.

Preparation.—It is obtained by heating gently, in a small glass retort, equal parts of strong muriatic acid, water, and chlorate of potash. The retort should only be subjected to the flame of a small spirit lamp, or an nflamed jet of hydrogen, which should be so situated as not to heat the body of the retort above the part containing the liquid; as this may cause an explosion. It is advantageous to interpose, as a support for the retort, a plate of tin, having a circular aperture of about an inch and a half in diameter. By these means, the application of the heat may be sufficiently restricted.

The gas may be received over mercury, although not without inconvenience; since either by its decomposition, or in consequence of some free chlorine with which it is accompanied, the mercury is partially converted into a chloride, or, as it would seem from its dark hue, a subchloride. The compound thus formed, by adhering to the glass, obscures it, so that the colour of the gas is seen with some difficulty.

The method, mentioned in the case of chlorine, of conveying the gas into a jar or bottle through a tube descending to the bottom, whence by its inferior weight the air is displaced, is recommended by Professor Silliman in the case of the gas under consideration; and latterly I have myself resorted to it with advantage.

Rationale.—It may be supposed that in this case the chlorate of potash is converted into a chloride of potassium, and that all the oxygen of the acid and alkali is liberated, making six atoms of oxygen. These six atoms may form three atoms of water with the hydrogen of three atoms of muriatic acid, and three atoms of protoxide with the three atoms of the chlorine of the same acid.

Properties.—Euchlorine has a peculiar and suffocating odour, which in some degree resembles that of chlorine, mingled with that of burnt sugar. Its colour is an orange-yellow, with a slight tinge of green. It first reddens, and then whitens litmus paper. At the temperature of 100° its elements separate with great violence, and with the disengagement of light and heat. After explosion, according to Sir Humphry Davy, it occupies one-fifth more space than before. Berzelius, however, alleges that a partial decomposition must have taken place in the experiments of Davy before the explosion. He estimates the expansion at one-half the previous volume of the gas.

When mingled with muriatic acid gas, and subjected to a high temperature, it i[illegible]esolved into chlorine and water. When brought in contact with phosphorus it explodes. The same effect is produced, after some time, by sulphur. Antimony or arsenic in powder, or Dutch leaf, frequently causes it to explode. This effect, however, may be due to the presence of uncombined chlorine.

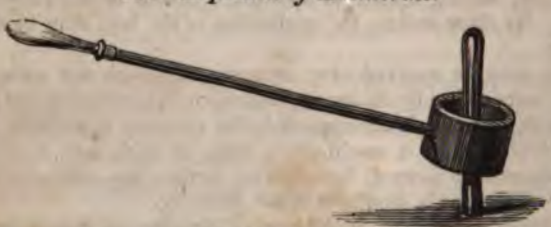
Incandescent coals, plunged into euchlorine, burn vividly at first, but are afterwards extinguished. This gas is slowly absorbed by mercury. Water absorbs eight or ten times its bulk, acquiring an acrid and almost acid taste, and a yellow colour.

Doubts are entertained whether this gas be not a mixture of chlorous acid with chlorine.

164. *Experimental Illustrations.*

Euchlorine, generated by the process abovementior and collected over mercury. Portions of euchlorine, ploded by Dutch gold, antimony, or arsenic, previou heated, and especially by phosphorus.

165. *Explosion of Euchlorine.*



A convenient and safe method of effecting the explosion of euchlc per se is represented in the preceding figure. The gas being introd into a strong tube of about $\frac{5}{8}$ths of an inch in diameter, and fifteen in in length, over mercury, on applying a heated metallic ring, an explc ensues. The gas at the same time loses its greenish-yellow colour, increases in bulk; each volume being converted into half a volume of gen, and one volume of chlorine.

The chlorine is subsequently absorbed by the mercury.

Thenard advises the application of a spirit lamp to produce the neces temperature. It is easier and more safe to use the hot ring. The must be supported by an iron wire, which has been overlooked in sk ing the figure.

Rationale.—Agreeably to the idea that aëriform fluids owe their r sive power to caloric, there ought, after an evolution of heat, to be duction of volume in any gaseous compound; but by the decompositi euchlorine, although caloric is evolved with explosive violence, the vol of the gaseous matter is increased.

The only explanation which I can give, is that the capacity for ca of the compound in this case, as in others, is greater than the sum o capacities of the constituents. Why the capacity of the compound sh be greater, and wherefore caloric should be more forcibly attracted b atom of oxygen and an atom of chlorine when united than when sepa I cannot explain. This and other analogous mysteries are no doubt nected with those of electricity, galvanism, and electro-magnetism.

Of Chlorous Acid, called also Tritoxide, Quadroxide and Peroxi Chlorine.

It is obtained over mercury by distilling one part of chlorate of po fused into a mass, at the bottom of a small glass retort, with abou parts of concentrated sulphuric acid. The evolution of the gas takes without heat at first, but to be completed requires a temperature ne 140°. This should not be exceeded, and the heat should be restricte the bottom of the retort as in the case of euchlorine. The proce replete with danger, as from slight causes this gas explodes with sur ce.

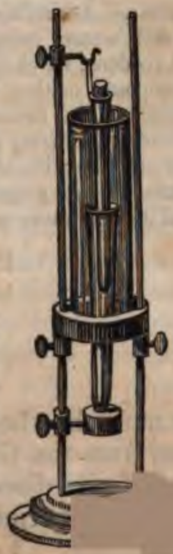
onale.—By the action of sulphuric acid on chlorate of potash,

; are produced, chlorous and oxychloric acid. The former is the gaseous state, the latter remains in union with the potash. em as if one portion of the chloric acid were displaced from its the potash by the superior affinity of the sulphuric acid, and uished a part of its oxygen to another portion of the same acid, ion with the alkali. The chlorate of potash is thus partially into an oxychlorate. The deoxidized chloric acid constitutes a which is designated by Berzelius as chlorous acid. It com- nascent with bases, forming the bleaching or disinfecting salts, known as chlorides of soda, potash, and lime, and which must lled chlorites.

s acid gas has a yellow colour, which is deeper than that of Its odour is somewhat aromatic, and bears no resemblance to lorine. It whitens a solution of litmus, without reddening it. jected to an electric spark, or to a temperature of 212°, it ex- 1 great violence, giving out light and heat and being converted ie and oxygen. Agitating the gas with mercury will sometimes e same result.

ıbsorbs seven times its volume of chlorous acid gas, acquiring a w colour, and a peculiar acrid taste, which is nevertheless not at The aqueous solution, when added in small quantities, possesses of reddening litmus, and when exposed directly to the sun's rays lorine, while oxychloric acid remains in solution. In a diffuse kes several weeks to effect this decomposition, and it does not at all in the dark. Faraday has found that chlorous acid gas quefied by subjecting it to great pressure. The resulting liquid ow colour. When this acid is brought in contact with a base, a it is decomposed, and a chlorate, chlorite, and chloride are formed. ng to Balard, chlorous acid contains only two atoms of oxygen. chlorine.

aratus for exhibiting safely the Explosion of Chlorous Acid.



joining figure represents an appara- hibiting, without danger to the spec- detonation of chlorous acid.

ube of nearly ⅜ths of an inch in dia- d sealed at one end, about as much f potash is introduced as will rise bottom about one inch. The mass ed is to be fused by means of a spi- or chauffer.

be, being then charged with a due of sulphuric acid, is corked gently, nded within a stout glass cylinder, drawing. It is then surrounded, ottom, by another tube, supplied with ter. At first, the hot water is applied at part of the tube which contains the as soon as the inner tube is pervaded iish-yellow colour, demonstrating the of the chlorous acid, the outer tube ; the water is to be raised, so that the e generally heated by it. An explo- follows, from the influence of which are protected by the glass cylinder.

Of Chloric Acid.

Preparation.—It may be obtained by passing chlorine through water, containing oxide of silver in suspension.

It is also procured by precipitating the potash from the chlorate by fluohydrosilicic acid, and filtration and evaporation. Should any chlorate remain, it may be removed by alcohol, which afterwards spontaneously evaporates. It was in the first instance discovered by precipitating baryta from the chlorate of baryta by sulphuric acid. In that way it cannot be obtained free from sulphuric acid; as it forms with this acid a compound more difficult to decompose than pure chloric acid. From this it differs also in reddening, without whitening litmus.

Properties.—It is an oleaginous liquid, colourless, sour, and astringent. It is inodorous, first reddens and then whitens litmus. It does not precipitate solutions of lead, mercury, or silver. It is partially decomposed by distillation. With muriatic acid it produces water and chlorine. It dissolves zinc and iron with disengagement of hydrogen gas.

Chloric acid is decomposed by a number of combustible bodies, and likewise by sulphurous and phosphorous acids, and sulphuretted hydrogen. Many bodies which do not act upon it in the dark, decompose it in the solar rays.

Of Oxychloric or Perchloric Acid.

Preparation.—After the chlorous acid has been liberated from chlorate of potash, agreeably to the explanation given, page 168, a portion of oxychlorate of potash remains. This is mingled with bisulphate of potash formed at the same time, but may be separated by repeated solution and crystallization, as the bisulphate is more soluble. When the oxychlorate has been thus purified, the acid may be obtained from it by distillation in a retort with its own weight of sulphuric acid, diluted with a like weight of water at the temperature of 280°. It is rendered more pure by carefully precipitating the sulphuric acid which comes over with it, by means of barytic water, and redistillation.

Properties.—According to Berzelius, it exists only as a liquid in combination with water, being limpid, colourless, and having a lively acid taste. It reddens, but does not subsequently bleach an infusion of litmus. It is decomposed neither by the solar rays, sulphurous acid, nor sulphuretted hydrogen. It dissolves zinc and iron with disengagement of hydrogen. It exercises strong affinities, and is the most enduring of the combinations of chlorine with oxygen; which is the more surprising, as it is in general true that in proportion as any one ingredient predominates in a compound it is the more easily separated in part.

* * *

SECTION III.

OF BROMINE.

This name has been given to a substance analogous to chlorine, from the Greek βρωμος, fetidity.

Bromine was discovered by Balard in 1826, in the mother waters of marine salt, at the salt works of Montpellier in France. Since then it has been found in the water of the Dead Sea, and in the greater part of the salt springs of the continent, especially those of Germany. In those of Theodorshalle near Kreuznach, a sufficient quantity has been found, to make it profitable to effect its extraction.

Common salt, in its natural state, often contains traces of the bromides of sodium or magnesium.

Preparation.—The mother water of marine, or common salt, is impregnated with chlorine, until it acquires a hyacinth-red tinge. The chlorine combines with the hydrogen and earth of a hydrobromate of magnesia, which exists in that water. The bromine, thus displaced, mingles with the water, which is to be washed with ether. The resulting ethereal solution of bromine, being treated with potash, a bromide of potassium is produced, which, heated in a retort with diluted sulphuric acid and manganese, yields bromine, as chlorine is obtained from a chloride by like treatment.

Properties.—Bromine is a liquid, and is so volatile, that a single drop is sufficient to fill a flask with its reddish-brown vapour. The specific gravity of bromine is 2.966, being nearly three times the weight of its bulk of water. It freezes at a temperature of from 7° to 12° below zero. It has, when frozen, a crystalline and leafy texture, with a lead-gray colour, and a lustre almost metallic. It boils at the temperature nearly of 89°, forming a vapour resembling that of nitrous acid, and more than five times as heavy as atmospheric air. It does not conduct electricity. Flame is extinguished in the vapour of bromine, acquiring a greenish colour previous to its extinction. Bromine is slightly soluble in water, and its solubility is not sensibly augmented by heat. The solution has an orange colour, and emits red fumes. It is more soluble in alcohol than in water, and in ether still more so than in alcohol.

It acts upon vegetable colours like chlorine, and indeed has a similar influence upon organic products generally; as it decomposes them in consequence of its affinity for hydrogen. Bromine combines with starch, producing a yellow compound. It corrodes the skin, producing a yellow tinge, which continues till the skin is renovated. In its habitudes with oxygen, hydrogen, sulphur, and phosphorus, it has a great analogy with chlorine, but generally its affinities are not so strong. When taken internally, bromine acts as a virulent poison.

Bromine is supposed to be one of the active substances in mineral springs, especially in those which contain common salt. By means of nitric acid bromine may be obtained from the mother waters in which it exists in the form of a deep brown precipitate; but there is much lost by its solution, and subsequent volatilization during the evaporation of the solvent.

167. *Experimental Illustration.*

Bromine exhibited as a liquid and in vapour.

COMPOUNDS OF BROMINE WITH OXYGEN AND CHLORINE.

Of Bromic Acid.

Bromine forms but one compound with oxygen, called bromic acid, which was discovered by Balard.

Preparation.—When sulphuric acid is added to bromate of baryta dissolved in water, a sulphate of baryta is precipitated, and bromic acid remains in solution, which may afterwards be concentrated by evaporation. See chlorates.

Properties.—Bromic acid, thus obtained, is a liquid of the consistence of syrup. If we endeavour to remove any farther portion of the water, the acid is decomposed into oxygen and bromine.

Bromic acid first reddens and then whitens litmus paper. It has a strong taste, acid but not caustic. Its odour is hardly perceptible. Sulphurous and phosphorous acid, and all the acids which have hydrogen for their radical, decompose it by removing the oxygen. Concentrated sulphuric acid produces the same effect by removing the water, without which bromic acid cannot exist.

Bromic acid is composed of one atom of bromine 78, and five of oxygen 40. Its equivalent is therefore 118.

Of Chloride of Bromine.

When a current of chlorine is passed through bromine, a liquid compound is produced of a reddish-yellow colour, but not so deep as that of bromine. This liquid is volatile, of an intolerable smell, producing tears, has an excessively disagreeable taste, and a colour resembling that of euchlorine.

Water dissolves this chloride, acquiring the power of bleaching litmus. Bases produce with its ingredients, a bromate, a bromide, and a chloride.

SECTION IV.

OF IODINE.

l be seen by the subjoined quotation from Thom-
organic Chemistry, that this element is widely
ıot copiously disseminated throughout nature.

> has been detected in various sea plants by Gaultier de Claubry.
> t in fucus saccharinus, fucus digitatus, fucus vesiculosus, fucus
> ıcus siliquosus, and fucus filum. Davy found indications of the
> f iodine in the ashes of fucus cartilagineus, fucus membranaceus,
> ns, fucus filamentosus, ulva pavonia, and ulva linza.
>
> yfe informs us that he found it in the ashes of fucus nodosus, fucus
> fucus digitatus, the ulva umbilicalis, and the common sponge.
> ıld not detect it in sea water, nor in any land vegetable.
>
> ırter found it in the sulphureous mineral waters of *Castelnovo*
> Piedmont, so celebrated for curing the goitre and other glandular
> M. Angelini had previously detected it in the mineral waters
> ı the same country. M. Boussingault detected it in a yellowish
> ıght from the province of Antioquia in South America, and em-
> cessfully as a cure for the goitre. M. Krüger of Rostock, found
> ıother ley of the Sülzer salt spring in Mecklenburg Schwerin.
> r found it in the mineral spring of Bonnington near Leith; and
> ny, Professor of Chemistry in Oxford, found it in various salt
> England.
>
> exists also in the mineral kingdom. Vauquelin found an iodide
> a mineral from Mexico which he analyzed. But he has given
> ion of the mineral, nor did he determine the proportion of the
> s."

the experiments of Dr. Steele, it appears that
xists in the mineral waters of Saratoga.

ration.—Iodine is obtained from the lixivium of
m which carbonate of soda is manufactured. After
oda has been crystallized, the residuum is concen-
ınd being heated with sulphuric acid, in a retort,
ıe passes over, and condenses in shining crystals
tense purple or black colour.

ationale of this process is analogous to that for
g chlorine by salt and sulphuric acid, excepting
presence of manganese is not indispensable; suf-
xygen being imparted, in the case of iodine, by
ial decomposition of the sulphuric acid into sul-
acid. But it will be more proper to recur to this
hereafter, in treating of the chlorides and chlo-
ıd iodides and iodates. Although not absolutely
ry, the presence of about one-sixth part of manga-

nese is advantageous by preventing the contaminating evolution of sulphurous acid.

Iodine may be precipitated from the mother waters of salts with which it is naturally associated, by a mixture of eight parts of sulphate of copper, and one of green sulphate of iron. From this precipitate iodine may be obtained by intense ignition, in a retort, with an equal quantity of dry peroxide of manganese.

Properties.—When solid iodine is of a bluish-black colour, friable, and almost insoluble. It stains the skin yellow. It fuses at 225° and volatilizes at 350°, in a beautiful violet vapour, whence it derives its name from the Greek ιωδης, violet-coloured. Its taste is acrid and hot, and continues for a long time in the mouth. When taken internally it acts as a poison. It is incombustible either in oxygen, or atmospheric air; but forms acids severally with oxygen, chlorine, and hydrogen, called iodic, chloriodic and iodohydric* acids. In its habitudes with the Voltaic pile, it is more electro-negative than any other matter, excepting oxygen, sulphur, chlorine, bromine, and probably fluorine. With starch, (fecula,) iodine produces an intensely blue colour; so that these substances are reciprocally tests for each other. When moistened it vaporizes perceptibly, producing an odour similar to that of chlorine, but which yet has a peculiar character. The specific gravity of iodine in the solid state is 4.946.

The vapour of iodine is alleged to have the highest specific gravity of any known aëriform fluid, being 8.716, or nearly nine times as heavy as atmospheric air. In condensing it is peculiarly prone to crystallize, assuming the form of an elongated octoedron, with a rhomboidal base. Water does not dissolve more than $\frac{1}{7000}$th of its weight, acquiring a russet colour, but no taste. When the water has a salt added to it, especially muriate or nitrate of ammonia, it dissolves a larger quantity of iodine. The aqueous solution does not give out oxygen in the solar rays, nor destroy vegetable colours. It has in other respects a great analogy to chlorine, and bromine, though more feeble in its affinities than either.

Soubeiran recommends that, in order to apply starch as a test for iodine, the liquid to be essayed should be rendered slightly acid by means of nitric acid. After this addition and that of the starch, it will, in the course of an hour, acquire successively a reddish tint, a brownish-red, a blue, and finally a black colour; or, in other words, the blue by its intensity, becomes equivalent to black.

---

* The term hydriodic has hitherto been applied to this acid, but Thenard, as well as myself, calls it iodohydric acid. The considerations which induced me to make this change will be given hereafter.

It has been alleged that in this way iodine may be detected in a liquid of which it forms only the $\frac{1}{450000}$th part.

Another mode is to include the liquid to be tested in a bottle made air-tight by means of a cork, from which is suspended a piece of moist paper sprinkled with finely powdered starch. If iodine be present, it will tinge the starch. It is alleged by Baup that iodine may be thus discovered, when existing in a liquid, in a proportion no greater than that of a millionth.

Balard recommends that, after boiling the liquid with a small quantity of starch, a solution of chlorine in water be added by means of a tube descending to the bottom. The chlorine, at the line of contact, disengages the iodine from its combinations, and enables it to act upon the starch. I resorted to a similar process, fifteen years ago, using sulphuric acid in the manner in which the chlorine is employed by Balard.

168. *Experimental Illustrations.*

A glass sphere containing iodine, on being warmed, appears filled with a violet-coloured vapour.

To a large glass vessel, containing some boiled starch diffused in water, a small quantity of iodine being added, the fluid becomes intensely blue.

Process for the extemporaneous Evolution of Iodine.

Heat nearly to the temperature of ebullition about two ounces of concentrated sulphuric acid, in a glass globe like that represented in the following figure.

It is preferable to have the whole of the globe heated by suspending it, with due caution, over a large charcoal fire. Then quickly transferring it to the iron tripod, previously heated, and furnished with a small bed of hot sand, throw into the acid about half a drachm of iodide of potassium, sometimes called hydriodate of potash. Instantaneously the cavity of the globe will become replete with the splendid violet vapour of iodine, which will soon after condense, on those portions of the glass which are first re-

frigerated, in crystals, symmetrically arranged, of great beauty and unusual size.

It is perhaps more convenient, as respects the manipulation, to have the globe suspended by a crane like that used for the suspension of large kettles, rendering it easy by a circular motion to swing them on or off the fire. By similar management the globe may be first kept over the fire till sufficiently hot, and then swung off to receive the salt. A method more attainable in the small way, is that of placing the vessel employed in a small iron skillet, in which it may be made steady by sand. Thus prepared, it may in the first place be conveniently held over the fire, and afterwards transferred to a table and supported without removing it from the skillet.

Of Iodic Acid.

When iodine is subjected to a current of chlorous acid gas, previously dried by passing over chloride of calcium, the gas is absorbed, and a yellow liquid produced. From this, heat expels all the chlorine of the acid, while its oxygen uniting with the iodine forms iodic acid.

Properties.—Iodic acid is an inodorous crystalline solid, much heavier than water, with an acid and astringent taste. It deliquesces in moist air, but remains unaltered when the air is dry. In water it is soluble, but is precipitated from it by alcohol, in which it is insoluble. Its aqueous solution first reddens and then whitens litmus.

With a great number of salifiable bases it forms salts, which detonate if mingled and ignited with any dry combustible matter. In common with bromic acid, it is decomposed by those acids which have hydrogen for their radical, and by many others which have not their highest proportion of oxygen. It contains one atom of iodine, and five of oxygen.

Of Hyperiodic and Iodous Acid.

An acid, containing more oxygen than iodic, has been recently discovered by Magnus, to which the name of hyperiodic has been given. But little has been ascertained respecting its properties. Sementini has asserted that he has discovered two additional compounds of oxygen with iodine, one of which he calls oxide of iodine, the other iodous acid. Their existence, however, requires farther confirmation. Consistently, the name of the acid called hyperiodic should be oxyiodic acid.

Of the Chlorides of Iodine.

According to Thenard, chlorine forms with iodine a protochloride and a perchloride. The former contains one atom of each ingredient, the latter consists of five atoms of chlorine and one of iodine.

The protochloride is the chloriodic acid of Davy.

To the perchloride the name of perchloriodic acid may be due. Thenard awards the appellation of acid to neither.

Chloriodic acid is obtained by subjecting iodine in excess to the action of chlorine. A liquid is produced of a deep reddish-brown colour, much heavier than water, and having in its mechanical properties a great analogy to bromine. It has an acid taste, and reddens litmus. Water dissolves it without sustaining or causing any decomposition, but abandons it to sulphuric ether. If the abovementioned process be so varied as to have an excess of chlorine, perchloriodic acid is produced, which is a crystalline and volatile substance of a yellowish-white colour, and emitting an effluvium so irritating as to produce tears and a sense of suffocation.

Of the Bromides of Iodine.

Bromine combines with iodine in two proportions. A protobromide is obtained when iodine is subjected in excess to the action of bromine. It is solid, and when warmed affords reddish-brown vapours, which condense into crystals of the same tinge, in shape resembling fern leaves. By the same process, when the proportions are reversed, a perbromide results, which is liquid. Both of these bromides are soluble in water, and bleach without reddening litmus. Subjected to the action of the Voltaic pile, bromine goes to the positive, iodine to the negative pole.

◆

SECTION V.

OF FLUORINE.

By many chemists, the existence is inferred of a principle called fluorine, which is conceived to be very analogous to chlorine, and even more active in its properties. I have no doubt of the existence of fluorine.

Fluorine exists in small proportions in mica, hornblende, paranthene, and in almost all the native phosphates. Traces of it are found in the teeth and bones of animals. It is capable of combining with phosphorus and sulphur. These combinations are obtained by distilling fluoride of mercury or lead, with sulphur or phosphorus in vessels of platinum. A sulphuret or phosphuret of mercury or lead, and a fluoride of sulphur or phosphorus, are produced. These are fuming liquids.

The fluoride of phosphorus is capable of combustion in oxygen; in which case phosphoric acid and gaseous fluorine have been supposed to result. Sir Humphry Davy supposed that fluorine might be isolated by these means.

I shall however defer, for the present, giving any farther account of this principle; as the intricate combinations in which it exists, will be more easily understood, when the student has acquired a knowledge of the substances with which it is united.

SECTION VI.

OF SULPHUR.

Sulphur is a mineral production, well known in commerce under the name of brimstone. It is sold both in rolls and in flowers. It is found pure in the vicinity of volcanoes, of which it is a product. In combination with metals it is widely disseminated. From some of its metallic compounds, which are known under the name of sulphurets, or pyrites, it is sublimed by heat, and, in condensing, assumes the pulverulent form, to which the name of flowers has been given.

Properties.—Sulphur is yellow, inodorous, and insipid, becomes electric by friction, and, when warmed within the hand, is fractured with a slight noise. It evaporates and burns with a feeble flame at 180°, and melts at 225°, and by pouring out the liquid portion, after the mass is partially congealed, it may be obtained in crystals. In close vessels at the temperature of 600° it vaporizes, and condenses in the well known form of flowers. The flowers are by the microscope ascertained to be crystalline, and are generally contaminated by a minute portion of sulphurous acid, which may be removed by repeated washing.

All the metals, when presented, in thin leaves or powder, to the vapour of sulphur without access of air, enter into combustion with it, forming compounds which have been designated as *sulphurets;* but which, as I have stated, ought to be called *sulphides.* Combustion also ensues when the metals in a divided state are heated with ur. The sulphides, formed with the metals of the earths and alkalies, are soluble in water. From the resulting solution the sulphur is thrown down by acids. Like phosphorus, sulphur is susceptible of a slow as well as quick combustion. In consequence of the low temperature at which it is capable of becoming converted by combustion into sulphurous acid, sulphur may be burned out of gunpowder without causing it to flash. If raised to the temperature of 369°, it enters into a more active reaction. The products of the combustion of sulphur are sulphurous acid, mingled with a small portion of *anhydrous* sulphuric acid. Berzelius alleges that when sulphur is rubbed on any body, a brick for instance, which has been previously warmed, though not sufficiently to inflame the sulphur, an extremely feeble blue flame is produced with a peculiar odour. This flame he conceives to be the effect of the evaporation, unaccompanied by any combustion; "since a cold body held above it is covered with the flowers of sulphur unchanged." This reason, however, appears insufficient; since the sublimation of one portion of the sulphur does not demonstrate that another is not oxidized, any more than the deposition of carbon upon a cold body exposed to a smoky flame, proves that another portion of carbon, arising from the same source, cannot at the same time be converted into carbonic acid, as is known to be the fact.

Some very curious anomalies have been observed respecting the phenomena of sulphur when kept over the fire after fusion, which the limits prescribed to this work will not allow me to introduce.*

169. *Experimental Illustrations.*

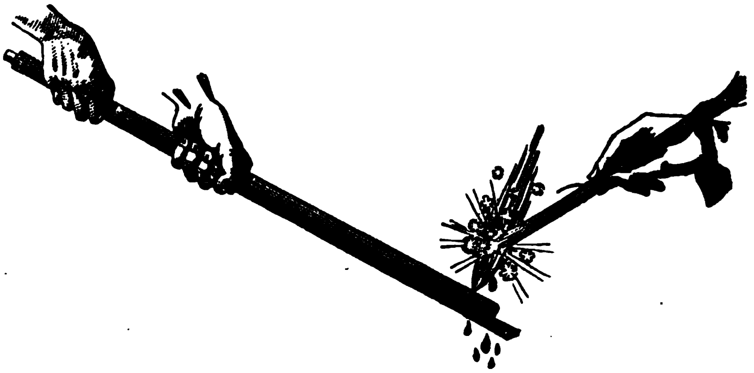
Sulphur exhibited in flowers and in rolls; also crystallized as above mentioned.

Combustion of Dutch gold leaf and of an iron bar by sulphur. Iron wire converted into a sulphide by the vapour of sulphur emitted in a jet from the touch-hole of a gun barrel, made red-hot in the vicinity of the aperture.

---

* Berzelius, Vol. I. p. 250.

170. *The Combustion of Iron by a Jet of Vaporized Sulphur.*



If a gun-barrel be heated red-hot at the but-end, and a piece of sulphur be thrown into it, on closing the muzzle with a cork, or blowing into it, an ignited jet of vaporized sulphur will proceed from the touch-hole. Exposed to this, a bunch of iron wire will burn as if ignited in oxygen gas, and will fall down in the form of fused globules, in the state of protosulphide. Hydrate of potash, exposed to the jet, fuses into a sulphide of a fine red colour.

COMPOUNDS OF SULPHUR WITH OXYGEN.

One atom of sulphur, 16,	With two atoms of oxygen, forms sulphurous acid, equivalent	32
	With three atoms of oxygen, forms sulphuric acid, equivalent	40
Two atoms of sulphur, 32,	With two atoms of oxygen, form hyposulphurous acid, equivalent	48
	With five atoms of oxygen, form hyposulphuric acid, equivalent	72

Of Hyposulphurous Acid.

This acid exists only in combination with salifiable bases, and of the salts formed I believe no useful application has been made. Any attempt to explain the method in which hyposulphites are produced, will be deferred until I reach the subject of the compounds formed by acids with metallic oxides.

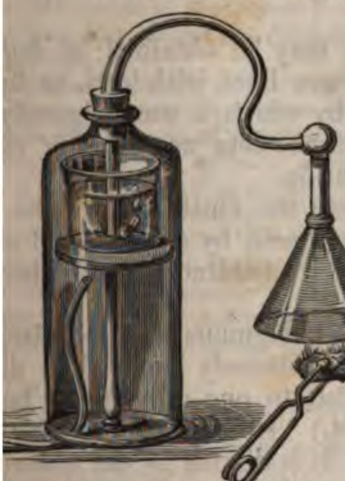
Of Sulphurous Acid.

Preparation.—It is formed by the ordinary combustion of sulphur, or by boiling sulphuric acid on sulphur, on mercury, or on any other substance by which it may be partially deoxidized.

Properties.—Sulphurous acid is a colourless gas, possessing the well known odour of burning sulphur. It is incapable of supporting combustion, and is deleterious to life, a spasmodic closure of the glottis following any attempt to respire it.

irst reddens and then bleaches litmus, and destroys vegetable co-
enerally. It is used on this account to bleach silk and wool. Sul-
s acid is soluble in water, which absorbs 43 times its bulk. When
ion of this gas is exposed to the air, it absorbs oxygen, and is con-
into sulphuric acid. This acid, with four times its bulk of water,
a crystalline hydrate, which melts under 40°, disengaging the
r part of the acid. After being rendered anhydrous by passing over
le of calcium, sulphurous acid gas, by exposure to a temperature of
, condenses into a colourless, transparent liquid, having the specific
y of 1.45. When dropped in vacuo on the bulb of a spirit ther-
ter, previously at 50° and surrounded with cotton, the intense cold
90° will be indicated. It is even said that alcohol has been frozen
manner. Sulphurous acid gas is decomposed at a red heat, either
drogen or carbon. It is displaced from its combinations by all the
except cyanhydric (prussic) and carbonic acid.

Impregnation of Water with Sulphurous Acid, by means of an appropriate Apparatus.



Into the open neck of a tall receiver, a recurved pipe is fastened, so as to descend a few inches below the neck. The other end of the pipe terminates in a brass socket, into which is inserted the stem of an inverted glass funnel. The receiver is placed over the shelf of the pneumatic cistern, covered about an inch deep with water, and includes a stand supporting a tumbler of the same liquid. A pipe, extending from a suction pump, rises within the receiver, nearly as high as the stand. If, under these circumstances, the pump be put into action,
nsequent exhaustion of the air from the receiver causes a rise into
the water from the cistern, until the resistance which this water op-
to a further elevation is greater than that opposed by the water in
mbler, to the entrance of air from the recurved pipe communicating
he funnel. The air of the funnel will then be drawn into the re-
through the liquid in the tumbler; and if sulphur, carbon, phos-
s, a candle, lamp, or any inflammable gas be placed, while burning,
the funnel, the fumes may be made to pass through the water, which
e coloured by litmus, or may contain lime, ammonia, baryta, or any
desirable agent, which it may be capable of dissolving or suspend-

Of Hyposulphuric Acid.

is acid is obtained by passing sulphurous acid gas through peroxide
nganese suspended in water in a finely divided state. If the mass be
cold, the peroxide is reduced to the state of protoxide, while the oxy-

gen forms with the sulphurous acid, hyposulphuric acid. This, with the protoxide, produces a salt, which, remaining dissolved, may be purified by crystallization. By the addition of sulphide of barium to a solution of the resulting crystals, the manganese is precipitated in the state of a sulphide, and hyposulphate of baryta is obtained. From this salt the hyposulphuric acid may be separated by sulphuric acid, and concentrated by evaporation in vacuo, till it acquires the specific gravity of 1.347. By heat or farther concentration, it is decomposed into sulphurous and sulphuric acid.

Hyposulphuric acid is a colourless, inodorous liquid, which reddens litmus, has an acid taste, and dissolves zinc with disengagement of hydrogen.

Of Sulphuric Acid.

Sulphuric acid has been known since the close of the fifteenth century, when it was obtained by Basil Valentine by the distillation of green vitriol, or sulphate of iron.

Preparation.—This acid may be obtained by burning sulphur and nitre in chambers lined with lead, or by the process above mentioned, by which it was originally obtained; whence the almost obsolete name, *oil of vitriol.* It is best purified by distillation.

I shall defer for the present the illustration of the process for procuring sulphuric acid by sulphur and nitre; also any exemplification of its habitudes with other bodies.

Properties.—It is a liquid, oleaginous in its consistency, caustic when concentrated, intensely acid when dilute. When three parts are added to one of water, a boiling heat is produced. (See 114.) Hot water explodes with it as with a melted metal. It is diluted by the absorption of moisture when exposed to the air. No acid equals it in the power of reddening litmus. When pure it is colourless and has but little smell.

Of the Sulphuric Acid of Nordhausen, and of Anhydrous Sulphuric Acid.

The sulphuric acid of Nordhausen differs from that in use in this country, in containing a portion of acid free from water, and, therefore, called anhydrous. This anhydrous portion being volatile, assumes the form of vapour, and, meeting with the moisture of the air, condenses into white fumes.

The fuming acid of Nordhausen is obtained by calcination and distillation from sulphate of iron, (known also by the name of green vitriol) contained in retorts of stone-ware. It may be obtained also from white vitriol or sulphate of zinc by similar treatment. The anhydrous acid may be separated from the other portion by gentle distillation, with the aid of a refrigerated receiver, previously well desiccated. It is a crystalline body resembling asbestos, and may be rubbed between the fingers like wax, without their being attacked. In the air it emits thick fumes having an acid smell. At a temperature above 64° it is liquid. Once congealed it cannot be fused without great care; as the temperature at which it is vaporized, is but little above that at which it liquefies. Hence it is apt to undergo a sudden enlargement of bulk which causes it to be thrown out of the containing vessel. When vaporized it forms a colourless gas. Neither in this state nor in its crystalline form has it any effect on litmus paper rendered perfectly dry. When passed through a red-hot tube of porcelain, it is resolved into oxygen and sulphurous acid.

Either caustic lime, or baryta enters into a species of combustion with this gas, forming with it a sulphate.

The solid anhydrous acid, thrown into water, produces a commotion resembling the effect of a hot iron, and, when mingled with an equivalent proportion of water, explodes with a force sufficient to fracture a glass vessel.

The fuming acid of Nordhausen is of use for the solution of indigo employed in dyeing; as the anhydrous acid answers better for this purpose than the aqueous.

It combines chemically in four proportions with water. The compound containing water in the least proportion is formed in some of the processes for producing the acid of Nordhausen. It is a crystalline body, which probably consists of 2 atoms of anhydrous acid and 1 of water. Four parts of the anhydrous acid and about 1 of water form the concentrated acid of the shops, of the specific gravity of 1.85, which is considered to contain 1 atom of water to 1 of acid. When the acid is to the water as 4 to 2, a compound results, of which the density is greater than the mean density of the constituents, and which probably consists of 2 atoms of water to 1 of acid. A similar alteration of the density follows the addition of water until the specific gravity is reduced to 1.632.

Of the Chlorides of Sulphur.

According to Thenard there are two chlorides which are both liquids. One contains 2 atoms of sulphur to 1 of chlorine; the other an atom of each ingredient. The protochloride is a yellow viscid oleaginous liquid, heavier than water, and which boils at 280°. The other is reddish-brown, volatile, fuming and acrid, and boils at 147°. Both are decomposed by water and alcohol.

Of the Bromide and Iodide of Sulphur.

The flowers of sulphur dissolve in bromine, producing a reddish, oleaginous fuming liquid. When iodine is heated gently with sulphur, it forms a brilliant crystalline iodide, of a steel-gray colour.

SECTION VII.

OF SELENIUM.

In 1817, Berzelius, examining, in concert with Gahn, the old method of preparing sulphuric acid, as practised at Gripsholm, in Sweden, discovered a sediment in the acid, partly red, partly brown, which, treated by the blowpipe, produced the odour of a rotten radish, and left a minute portion of lead. The odour thus evolved had been considered by Klaproth as an indication of tellurium. In consequence, Berzelius took care to collect all the deposition, produced in the manufacture of sulphuric acid during some months; no other sulphur than that of Fahlun being employed. The discovery of a new substance resulted, to which he gave the name of selenium, from the Greek word σεληνη, the moon, suggested by its analogy with tellurium, named from tellus, the earth.

Selenium seems much distributed throughout nature. In Sweden it has been found combined sometimes with copper and silver, sometimes with copper only. A small quantity has been detected in cubic galena. In Norway it has been discovered united with tellurium and bismuth; in the Hartz, combined with lead, copper, and mercury. Stromeyer has found it in a mineral from the Lipari islands, combined with sulphur.

Preparation.—From the deposition in which it exists, as above stated, selenium is extricated by solution in aqua regia, precipitation by sulphuretted hydrogen, solution in the same solvent, precipitation by potash, filtration and evaporation of the residual liquid, desiccation of the resulting mass, and sublimation with the addition of sal ammoniac. Selenic acid, produced by the reaction of the selenium with the oxygen in the aqua regia, is saturated by the potash, and afterwards deoxidized by the hydrogen of the ammonia in the sal ammoniac employed, the selenium being sublimed by the heat.

Properties.—Selenium, on cooling after distillation, assumes a shining surface of a deep reddish-brown colour, with a metallic brilliancy resembling that of the blood-stone (hæmatite). Its fracture is conchoidal, vitreous, of a lead-gray, with metallic lustre. Very slowly refrigerated after fusion, its surface becomes granulated and uneven, of a reddish-gray, and devoid of lustre. By quick refrigeration the characters above indicated result. Selenium has little tendency to crystallize, yet it is capable of separating in a crystalline pellicle, or of forming a crystalline vegetation upon the sides of the vessel, from its solution in the state of a selenhydrate. When precipitated cold from a diluted solution, whether by zinc or sulphuretted hydrogen, it is red like cinnabar. But if this precipitate be boiled, it turns black and consolidates, becoming heavier. When pulverized, selenium becomes of a deep red, and likewise when in very thin layers. With heat it softens, and at the boiling point of water, acquires a semifluidity, becoming completely fluid at a temperature somewhat higher. In cooling it remains soft for a long time, and may, like heated sealing-wax, be drawn out into filaments. These, by reflected light, are gray with some metallic brilliancy, but, by transmitted light, are transparent, and of a ruby-red colour.

When selenium is heated nearly to redness in a distillatory apparatus, it assumes, with ebullition, the form of a vapour of a yellow colour, deeper than the hue of chlorine, yet lighter than that of sulphur. This vapour condenses in the neck of a retort in black drops, which coalesce like those which are formed by the condensation of mercury. When condensed with access of air, selenium appears like a red fume, and is deposited in a state analogous to the flowers of sulphur, but of a cinnabar-red colour. The smell of a radish is only perceived when the heat is sufficient to be productive of oxidation.

The specific gravity of selenium is from 4.3, to 4.32.

Compounds of Selenium with Oxygen.

Selenium has but a feeble affinity for oxygen, yet forms a volatile oxide, which has the smell either of radish or decayed radish. It forms also two acids, the selenious and selenic. The latter of these is isomorphous with sulphuric acid. See page 130.

Selenious acid is procured by the combustion of selenium in oxygen gas, or by the action of nitric or nitromuriatic acid.

Selenic acid is obtained by the deflagration of nitre with selenium in a hot crucible; a seleniate of potash results, which is decomposed by nitrate of lead, and the resulting seleniate of lead is decomposed by sulphuretted hydrogen. The sulphuret of lead precipitates, while selenic acid is dissolved in the water employed. When heated to 280 degrees, it attains its highest concentration, and at 290 degrees is decomposed into oxygen and selenious acid.

The highest specific gravity of selenic acid is 2.6. It resembles sulphuric acid in its consistency, in its evolving heat by dilution with water, and in the power of dissolving iron and zinc, with the evolution of hydrogen. It cannot be rendered anhydrous. When its density is at the maximum, it contains 16 per cent. of water. With the aid of heat, it oxidizes and dissolves copper and even gold, but not platinum. With chlorohydric acid, it constitutes a sort of aqua regia, which dissolves both gold and platinum. Its salts cannot be distinguished from the sulphates, unless by the property of detonating with carbon at a red heat, and that of causing an evolution of chlorine, when boiled with muriatic acid. Selenic acid may be separated from sulphuric acid by saturation with potash, and ignition with sal ammoniac. The selenic acid is decomposed into selenium by the hydrogen of the ammonia.

Selenium combines with chlorine and bromine, and with sulphur in every proportion.

As there is not one of the metals which have decided pretensions to the metallic character, which is not an excellent conductor of both heat and electricity, and as metallic brilliancy is another striking attribute of the metallic genus, I cannot understand wherefore selenium, which is admitted to be destitute of the two first mentioned characteristics, and to possess the last imperfectly, should be received into the class of metals; while carbon, which in the form of plumbago is endowed with them all, is excluded. I cannot consider selenium as a metal. It is stated to have the brilliancy of hæmatite, which is, I conceive, inferior in that respect to plumbago, which Berzelius considers as pure carbon.

SECTION VIII.

OF TELLURIUM.

A metal has been found in the veins of auriferous silver in the mines of Transylvania, which has been called tellurium. It is found also in small quantities in Norway, united to selenium. Tellurium has likewise been discovered in Connecticut.

Tellurium displays a metallic brilliancy, and is of a colour between that of tin and antimony, and of a lamellated structure. It is found chiefly in the state of an alloy with gold and silver. It fuses below a red heat, and above that temperature is volatilized. When heated before the blowpipe, it takes fire, and burns with a blue flame bordering on green, and is dissipated in gray pungent fumes, which have sometimes the smell of horse radish. This smell is ascribed by Berzelius to the presence of selenium.

Tellurium may be oxidized either by combustion or by nitric acid. The oxide, exposed before the blowpipe upon charcoal, is decomposed with explosive violence.

Berzelius alleges that tellurium will dissolve in concentrated sulphuric acid without being oxidized, in which it differs from other metals. The colour of its solution in the acid is purplish-red. It is more especially entitled to our notice on account of its great analogy to sulphur and selenium, and by reason of its forming both acids and bases, which uniting form telluri-salts. This is the ground upon which it has been included in his *amphigen class* by Berzelius, and upon which I have included it among the *basacigen bodies*.

OF RADICALS.

Radicals are bodies capable of forming with a basacigen body either an acid or a base, or both, and which do not form acids or bases with each other.

Radicals are divided into those which are *metallic*, and those which are *non-metallic*.

OF NON-METALLIC RADICALS.

The bodies which I place under this head are:—

Hydrogen,
Nitrogen,
Phosphorus,
Carbon,
Boron,
Silicon,
Zirconion.

SECTION I.

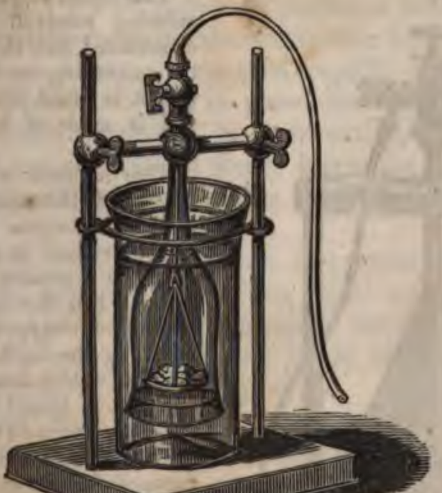
OF HYDROGEN.

ts gaseous state, it is the principal constituent of all
ry flame. Combined with oxygen or carbon, or
it is found in water, and all vegetable and animal
nces. It derives its name from υδωρ, water, and
to produce.

paration.—Per se, hydrogen exists only in the gas-
tate. In this form it may be obtained by the reac-
f diluted sulphuric or muriatic acid with zinc or
or of steam with iron turnings, made red-hot in a
arrel. It may be evolved in a state of purity, and
quently destitute of odour, from pure water by Vol-
gency, or by reaction with an amalgam of potas-
but if an acid or a salt be added, the gas acquires
ual odour.

. Self-regulating Reservoir for Hydrogen and other Gases.

following figure represents a self-regulating reservoir for hydrogen



very perspicuous engraving can require but little explanation.
the glass jar without to contain diluted sulphuric acid; the in-
bell, within the jar, to contain some zinc, supported on a tray of
suspended by wires of the same metal from the neck of the bell.
ck being open when the bell is lowered into the position in which
presented, the atmospheric air will escape, and the [illegible] ering
ity of the bell, will, by its reaction with the zinc,

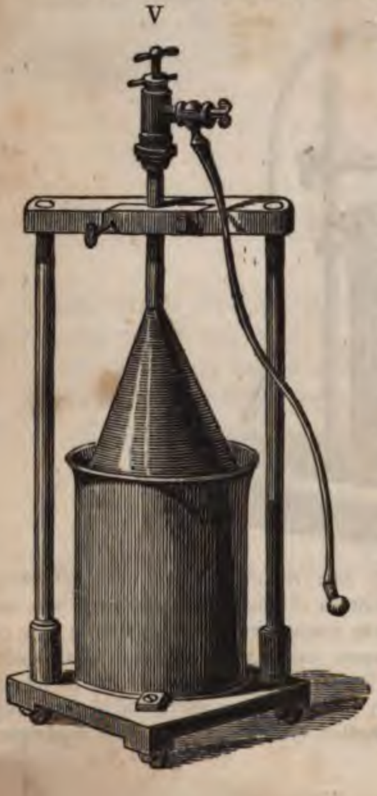
gas to be copiously evolved. As soon as the cock is closed, the hydrogen expels the acid from the cavity of the bell; and, consequently, its reaction with the zinc is prevented, until another portion of the gas be withdrawn. As soon as this is done, the acid re-enters the cavity of the bell, and the evolution of hydrogen is renewed and continued, until again arrested, as in the first instance, by preventing the escape of the gas, and consequently causing it to displace the acid from the interior of the bell, within which the zinc is suspended.

The principle of this apparatus is analogous to that which was contrived by Gay-Lussac. I had employed the same principle, however, when at Williamsburg, to moderate the evolution of carbonic acid, before I had read of Gay-Lussac's apparatus.

I prefer the modification above described. In the first place, it is internally more easy of access for the purpose of cleansing; secondly, it is much better qualified for containing sulphuret of iron, or marble, for generating sulphuretted hydrogen, or carbonic acid gas; and thirdly, by raising the bell glass, the pressure may be removed.

In the other form, the pressure on the gas is so great that, unless the tube, the cock, and their junctures be perfectly tight, there must be a considerable loss of materials; since the escape of gas inevitably causes their consumption, by permitting the acid to reach the zinc, or other material employed.

173. *Large Self-regulating Reservoir for Hydrogen.*



This figure represents a self-regulating reservoir for hydrogen, constructed like that described in the preceding article; excepting that it is about fifty times larger, and is made of lead, instead of glass.

This reservoir is attached to the compound blowpipe, in order to furnish hydrogen, and may, of course, be used in all experiments requiring a copious supply of that gas. When this is to be applied to the hydro-oxygen, or compound blowpipe, the knob at the end of the pipe, which has an orifice on one side, is placed under the gallows, G, (seen in the fig. of the compound blowpipe, page 116) and fastened air-tight to the pipe of that instrument, by the pressure of the screw of the gallows.

The gas is retained, or allowed to flow through the pipe, by means of the valve cock, V, which is much less liable to leak than one of the common form. See Appendix for an account of the valve cock.

Properties of Hydrogen.—It is the lightest of all ponderable substances. One hundred cubic inches weigh only 2.13 grains. Its weight to that of oxygen is as 1 to 16. Its specific gravity, the gravity of air being assumed as 1, is 0.0689. It is about 200,000 times lighter than mercury, and 300,000 times lighter than platinum. In its ordinary state it smells unpleasantly. When pure it is without odour.

The respiration of hydrogen, mixed with the same proportion of oxygen as exists in atmospheric air, is not attended by any oppressive sensations; yet a profound sleep is said to have been induced in animals surrounded by such a mixture. When breathed either in this way or unmixed, it will be found to produce a ludicrous alteration in a man's voice, making it shrill and puerile, and so out of character as not to be recognised. Sound is said to move in this gas with a velocity three times as great as in the atmosphere.

According to the experiments of Leslie, the sound of a clock bell was as feeble in hydrogen as in air rarefied one hundred times. By no degree of pressure which has been tried, can hydrogen be condensed into a liquid. In consequence of its levity, it escapes rapidly from an open vessel, unless inverted. It is pre-eminently inflammable, yet a taper when immersed in it is extinguished. A jet of it, ignited, appears like a feebly luminous candle flame, and, if surrounded by a glass tube, produces a remarkable sound.

The specific heat of hydrogen is greater than that of any other gas, being to that of an equal weight of air as 13.08 is to 1, and to that of an equal weight of water as 3.88 to 1. Its refracting power is ten and a half times greater than that of the atmosphere.

When mixed with oxygen or atmospheric air, and subjected to flame, an electric spark, or a wire ignited by galvanism, it explodes. With chlorine it explodes under like circumstances, and likewise in the solar rays. In burning it disengages sufficient heat to melt 315 times its weight of ice. Dobereiner discovered that platinum sponge, a cold metallic congeries, becomes ignited on entering a mixture of hydrogen with oxygen gas, and causes it to inflame by an agency which has not been satisfactorily elucidated. It has since been discovered that palladium, rhodium, and iridium possess this property in nearly the same degree. I have ascertained that if asbestos, charcoal, or clay be soaked in chloride of platinum, and afterwards desiccated and heated red-hot, the property of inflaming a mixture of hydrogen and oxygen is acquired.

174. *Experimental Illustrations of the Properties of Hydrogen.*

Levity of the gas demonstrated by the ascension of a balloon, or by the effect of filling, with hydrogen, a glass globe balanced upon a scale beam. See article 62. Effect upon the voice shown. Inflammation of a gaseous mixture of hydrogen with atmospheric air by platinated asbestos, or platinum sponge. Apparatus for lighting a candle by a jet of hydrogen from a self-regulating reservoir, either by the electric spark or platinum. Cannon, charged with a mixture of hydrogen and oxygen, fired by a galvano-ignition apparatus, article 111.

175. *Candle extinguished and re-lighted by Hydrogen.*

If a lighted candle be introduced into a wide mouthed inverted phial, filled with hydrogen gas, the flame of the candle will be extinguished from the want of oxygen. Meanwhile, at the mouth of the bottle, where there is a sufficient access of air, the gas will have taken fire, and will burn with a lambent flame scarcely visible in daylight. Hence if the candle be slowly withdrawn, it will be re-lighted as it passes through the flame.

176. *Philosophical Candle.*

Granulated zinc, or turnings of iron, being introduced into a glass flask, so as to occupy about one-fourth of its capacity, provide a suitable cork, so perforated as to receive a glass tube terminating in an orifice just large enough to admit a common brass pin. Pour upon the zinc five parts of water, and adding one of sulphuric acid; fasten the cork, with its tube inserted, into the mouth of the flask. After all the atmospheric air has escaped from the vessel, on applying the flame of a candle to the orifice of the tube, it will be surmounted by an inflamed jet of hydrogen, which has been called the philosophical candle.

The light given out by the flame of pure hydrogen, is, nevertheless, wholly incompetent to answer the purpose of candle light; but I have ascertained, that the addition of a small quantity of spirit of turpentine to the materials obviates this defect.

pplication of Hydrogen and Oxygen in Eudiometry.

he explosive union of hydrogen with oxygen has been h resorted to in the analysis of gaseous mixtures coning either.

or this purpose a stout tube, sealed at one end, at the r shaped like a trumpet, has holes drilled into it, near sealed end, for the introduction of metallic wires, the of which approach near enough to each other, within ube, for the passage of an electric spark. A known me of the explosive mixture being introduced into the , and ignited by a spark from an electrophorus or an rical machine, and the residual air being transferred graduated tube, the deficit caused by the process is rtained.

he glass tube, employed in this experiment, with its rtenances, is called a eudiometer.

his appellation was at first applied to the instruments in the analysis of atmospheric air, of which one-fifth is oxygen gas; but it has since been applied to all uments, employed in measuring the results of pneu-chemical analysis.

177. *Of the Volumescope.*

Experiments performed with eudiometers such as I have been mentioning, do not serve to make the steps of the process evident to a numerous class, so as to enable them to judge of the result by inspection. In order to attain this object, I have contrived the apparatus represented on the opposite page, which I have called a volumescope, as I find it very inconvenient not to have a name for every variety of apparatus.

It consists of a very stout glass tube, of 36 inches in height, and tapering in diameter inside from 2 and $\frac{1}{8}$th to 1 and $\frac{1}{8}$th inches. The least thickness of the glass is at the lower end, and is there about $\frac{5}{8}$ths of an inch. There is an obvious increase in thickness towards the top, within the space of about 6 inches. The tube is situated between the iron rods, I I, which are riveted, at their lower ends, to a circular plate of the same metal, let into the lower surface of a square piece of plank, P. This piece of plank supports the tube, so as to be concentric with an aperture corresponding with the bore of the tube, and constituting effectively its lower orifice. The upper orifice of the tube is closed by a stout block of mahogany, which receives a disk of gum elastic in a corresponding hollow, made by means of a lathe, so as to be of the same diameter as the end of the tube. Into a perforation in the centre of the mahogany block, communicating with the bore of the tube, a cock, c, furnished with a gallows screw, is inserted. Through the block, on each side of the perforation, wires are introduced, so as to be air-tight.

To the outer ends of these wires two gallows screws, g g, are soldered; to the inner ends a platinum wire, so as to form a galvano-ignition apparatus, analogous to that already described and illustrated, page 107, article 111.

The apparatus being so far prepared, let it be firmly fixed over the pneumatic cistern, so that the water may rise about an inch above the lower extremity of the tube. To the gallows screws, *g g*, attach two leaden rods, severally proceeding from the poles of a calorimotor. By means of a leaden pipe, produce a communication between the bore of the cock and an air pump, so that by pumping the air from the cavity of the tube, the water of the cistern may be made to rise into the space thus exhausted of air. On each side of the tube, and between it and each iron rod, there are two strips of wood S S, scored so as to graduate about seven inches of the tube into eight equal parts. These parts were measured by introducing into the tube, previously filled with water, exactly the same bulk of air eight times, and marking the height of the water after each addition. By these means the instrument is graduated into eight parts of equal capacity; and we are by aid of it enabled to measure the gases, and to notice the diminution of volume resulting from their spontaneous reaction, or that which may be induced by the ignition of the wire.

The apparatus being so far prepared, and the tube exhausted of air so as to become full of water, close the cock leading to the air pump, and introduce two volumes of pure hydrogen and one volume of pure oxygen, which may be most conveniently and accurately effected by the sliding rod gas measure. The plates of the calorimotor being in the next place excited by the acid, the ignition of the platinum wire ensues, and causes the hydrogen and oxygen to explode. When they are pure, the subsequent condensation is so complete, that the water will produce a concussion as it rises forcibly against the gum elastic disk, which, aided by the mahogany block, closes the upper orifice of the tube.

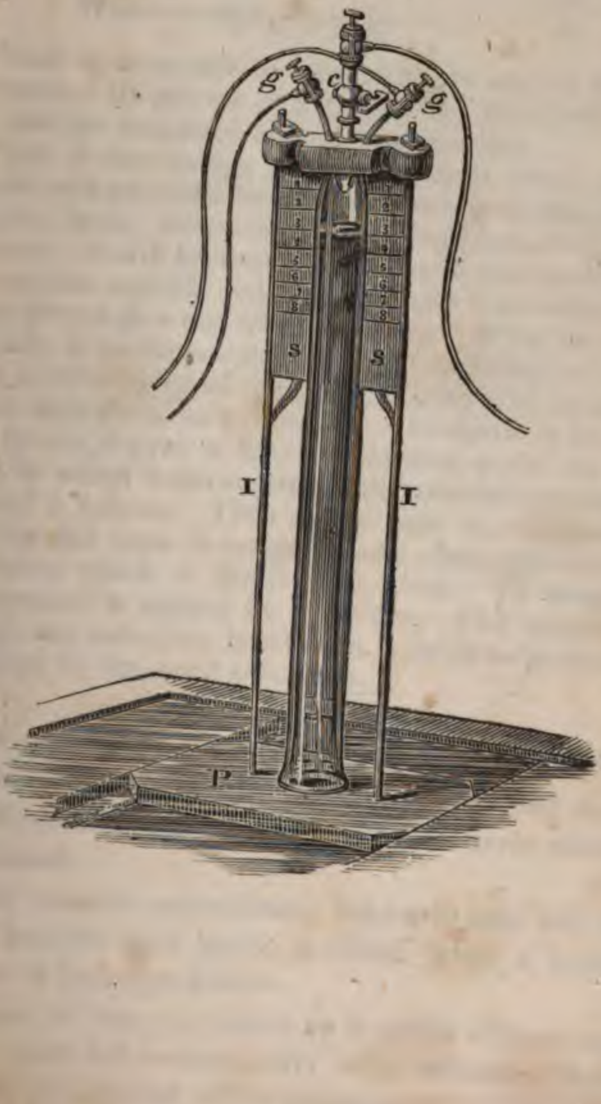
If the preceding experiment be repeated with an excess of either gas, it will be found that a quantity, equal to the excess, will remain after the explosion. This is very evident when the excess is just equal to one volume, because, in that case, just one volume will remain uncondensed. By these means, a satisfactory illustration is afforded of the simple and invariable ratio in which the gaseous elements of water unite, when mixed and inflamed; which is a fact of great importance to the atomic theory, and to the interesting theory of volumes which hereafter I shall have occasion to notice.

COMPOUNDS OF HYDROGEN WITH OXYGEN.

Of Water.

This liquid is produced by the combustion of hydrogen gas with oxygen gas. It may be decomposed by passing it in steam over iron, ignited in a gun barrel; also by the aid of acids, by the alkaline metals, by sulphurets and phos-

Volumescope.



phurets, by electricity, by galvanism, and by vegetable leaves. Water is vaporizable by heat, and evaporable by the joint influence of heat and air.

The equivalent of oxygen being	8
And that of hydrogen	1
Water is represented by	9

Water is necessary to some crystals and to galvanic processes. Its powers as a solvent are peculiarly extensive, and are increased by heat and pressure.

Water is one, among other substances, which acts as an acid with powerful bases, while with powerful acids it acts as a base. Berzelius, in some instances, calls it hydric acid. It will be seen as we proceed that it combines with various metallic oxides, especially those which constitute the alkalies and alkaline earths. With the latter especially it produces much heat in combining, as exemplified in the slaking of lime; and in several of its combinations with them, its affinity is too energetic to be overcome by any degree of heat. Excepting acids, any compound in which water exists as an essential constituent, is called a *hydrate*. Thus slaked lime is a hydrate of lime; but this term is inappropriate, when applied to the compounds which it forms with acids. To them the term *aqueous* is applied by Berzelius. The absence of water in any substance in which it is liable to be present, is signified by the word *anhydrous*.

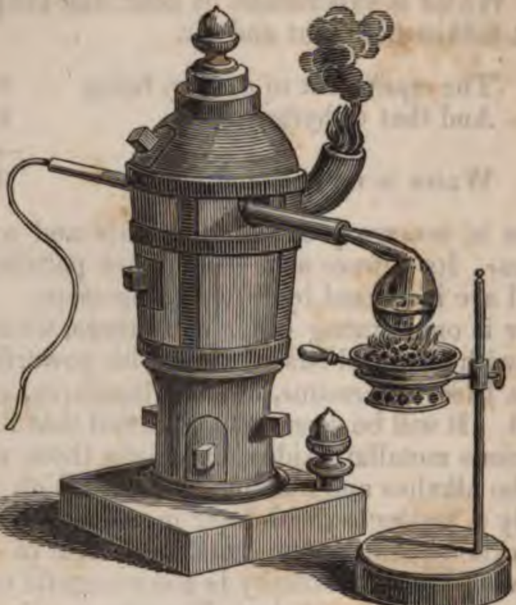
178. *Experimental Illustrations of the Agency of Water.*

No reaction ensues between tartaric acid and carbonated alkali until water is added, when a lively effervescence ensues.

In like manner, concentrated sulphuric acid and zinc remain inactive until water is added, when a copious evolution of hydrogen follows.

If nitrate of copper be rolled up in tinfoil without moisture, the mass will remain inert; but if moistened before it is rolled up, ignition will be produced.

179. *Steam decomposed by Ignited Iron.*



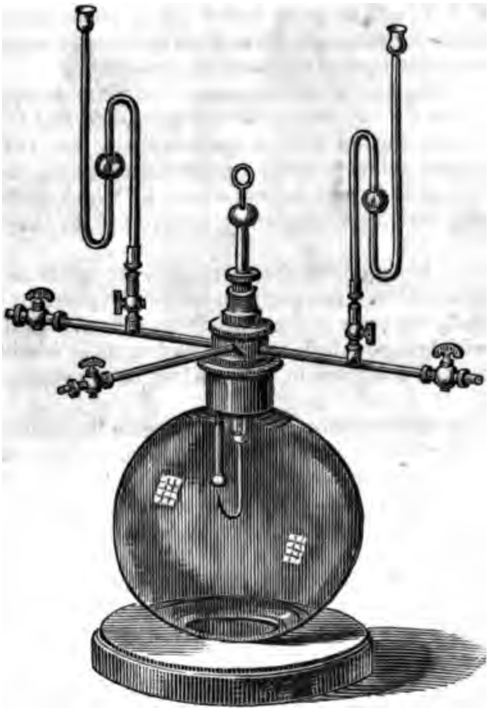
Having introduced some turnings of iron or refuse card teeth into an old musket barrel, lute into one end of it the beak of a half-pint glass retort, about half full of water; into the other end, a flexible leaden tube. Lift the cover off the furnace, and place the barrel across it, so that the part containing the iron turnings may be exposed to the greatest heat. Throw into the furnace a mixture of charcoal and live coals. The barrel will soon become white-hot. In the interim, by means of a chauffer of coals, the water being heated to ebullition, the steam is made to pass through the barrel in contact with the heated iron turnings. Under these circumstances, the oxygen of the water unites with the iron, and the hydrogen escapes in the gaseous state through the flexible tube.

The decomposition of water by sulphurets, phosphurets, and the alkaline metals will be illustrated in due time.

180. *Water produced by an inflamed Jet of Hydrogen.*

The recomposition of water may be rendered evident, by means of the philosophical candle, 176, or any other inflamed jet of hydrogen, situated within a large glass globe. The glass becomes immediately covered with a dew, arising from the condensation of aqueous vapour, produced by the union of the oxygen of the air with the hydrogen.

181. *Lavoisier's Apparatus for the Recomposition of Water.*



This apparatus consists of a glass globe, with a neck cemented into a brass cap, from which three tubes proceed, severally communicating with an air-pump, and with reservoirs of oxygen and hydrogen. It has also an insulated wire for producing the inflammation of a jet of hydrogen by means of an electric spark. In order to put the apparatus into operation, the globe must be exhausted of air, and supplied with oxygen to a certain extent. In the next place, hydrogen is allowed to enter in a jet, which is to be inflamed by an electric spark. As the oxygen is consumed more is to be admitted.

I have employed a wire ignited by galvanism to inflame the hydrogen in this apparatus, and conceive it to be a much less precarious method than that of employing an electrical machine, or electrophorus.

182. *Description of an improved Apparatus for the Recomposition of Water.*

This apparatus is represented by the opposite engraving. An inverted bell glass, with a conical neck, is so closed at the apex in the making, as to form a transparent converging cavity, suitable to render the presence of a very small quantity of any contained liquid perceptible to the eye.

By means of the screw rod and plate frame, (page 94,) this bell glass is secured in an inverted position and made air-tight. With the aid of three valve cocks, V V V, and as many leaden pipes, communications with an air-pump, a barometer gauge, and a receiver sufficiently supplied with oxygen, may be severally opened or closed at pleasure.

Through a stuffing box which surmounts the plate, a copper pipe, P, is so passed as to occupy the axis of the bell glass, and that of a coil of platinum wire, appertaining to a galvano-ignition apparatus, (111.) The copper pipe terminates below in a small platinum tube, and above, outside of the receiver, in a cock C, and gallows screw, by which and a leaden pipe, a communication with a self-regulating reservoir of hydrogen is at command.

The apparatus having been thus arranged, the bell is to be exhausted, and oxygen admitted, until the gauge indicates the pressure within the receiver to be nearly the same as that of the atmosphere. In the next place, the platinum wire being ignited, a jet of hydrogen is admitted, which of course inflames, and continues to burn so long as the supply of the gases is kept up.

Soon after the inflammation of the hydrogen, the resulting water will be seen to coat the interior of the bell glass in drops, resembling a heavy dew, and, continuing to accumulate, will descend in streams into the converging neck of the bell glass. By surrounding this with cold water, the condensation may be expedited, and the deposition of water soon rendered strikingly evident.

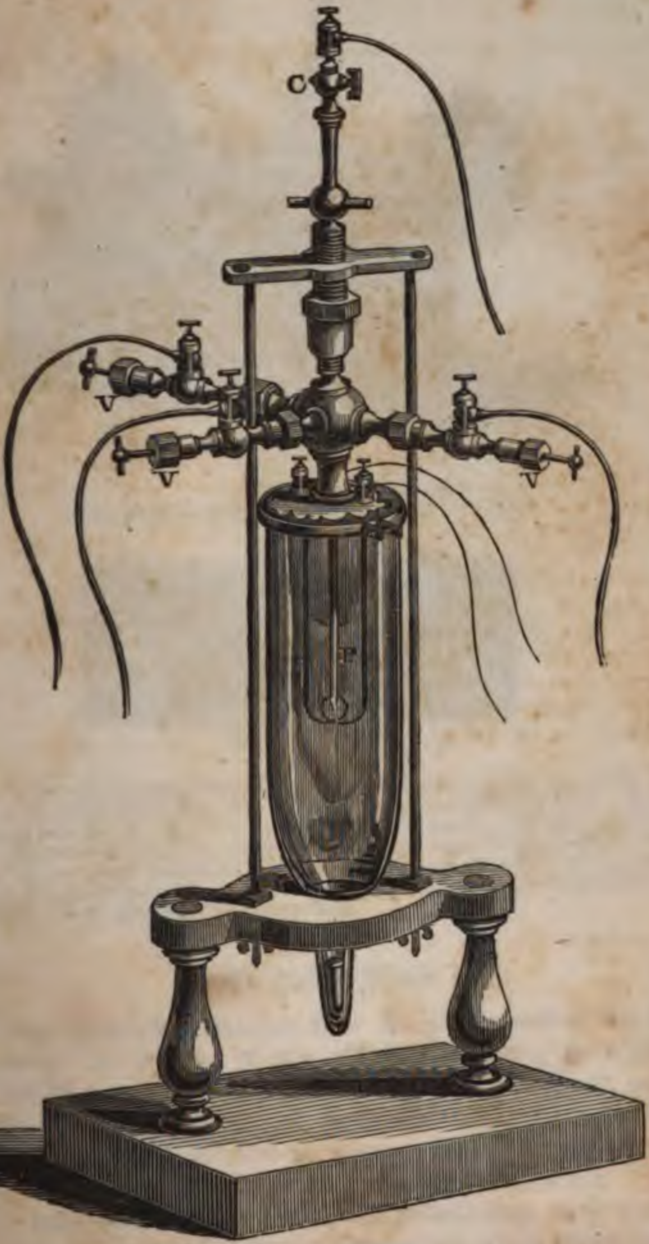
I will here give an engraving and description of the calorimotor, which I employ in the above experiment, and in others requiring the vivid ignition of about two inches of platinum wire, No. 24.

183. *Description of a Galvanic Machine for producing Ignition.*

This machine (see cuts, next page) consists of 16 plates of zinc, and 20 of copper, each 12 inches by 7, arranged in four galvanic pairs. The plates are supported within a box with a central partition of wood, A B, dividing it into two compartments. Each of these may be considered as separated into two subdivisions, by four plates of copper between the letters C C. Of course the box may be considered as comprising four distinct spaces, 1, 2, 3, and 4. The circuit is established in the following manner. Between the zinc plates of compartment 1, and the copper plates of compartment 2, a metallic communication is produced, by soldering their neighbouring corners to a common mass of solder with which a groove in the wooden partition between them is filled. With similar masses of solder, two grooves severally made in the upper edges of each end of the box are supplied. To one of them, the corners of all the copper plates of space 1, and of all the zinc plates of space 4 are soldered. To the other the zinc plates of space 2, and the copper plates of space 3 are soldered in like manner. Lastly the zinc plates of compartment 3 are connected by solder in a groove, and the copper plates of compartment 4 are in like manner connected by solder in another groove. Upon the ends, S S, of the solder just mentioned, the gallows screws are severally soldered, and to these the rods, P P, called poles, are fastened.

The zinc and copper surfaces of 1 and 2 communicating, have their naturally opposite electric powers exalted, and induce in the plates with which they are alternated, a like exaltation still higher. By the communication of the latter with the

Apparatus for the Recomposition of Water.



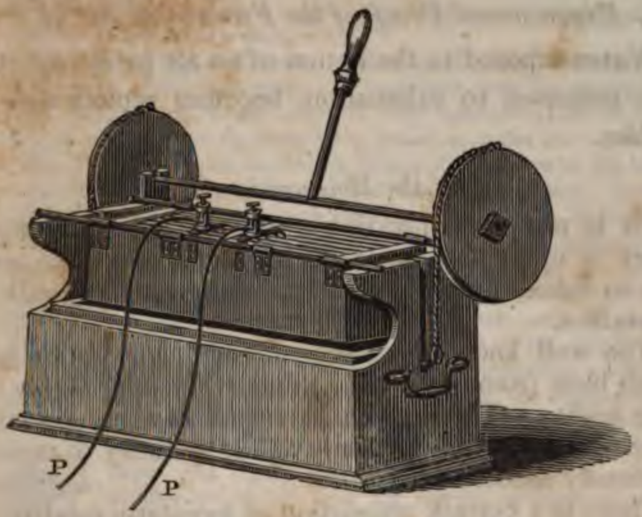
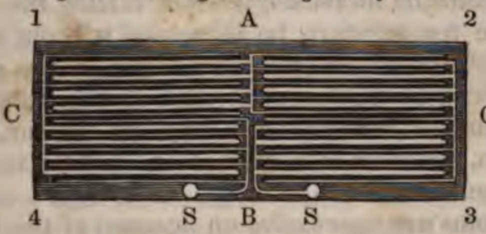


Diagram illustrating the Arrangement of the Plates.



surfaces in 3 and 4, a similar effect is induced; and again by induction the electric powers of the plates alternating with those last mentioned are augmented. Hence a discharge between the latter will have a quadruple intensity, and hence the poles, or rods, communicating with the gallows screws, soldered as above described to the zinc and copper plates mentioned, will make a discharge through any conductor, whenever the apparatus is put into operation by raising the acid, so as to enable it to surround and act upon the galvanic surfaces.

Of the Air in Water.

Water naturally contains air. It is to receive the influence of the oxygen of the air thus existing in water, that fishes are furnished with gills, which perform to a certain extent the office of lungs in decarbonizing the blood. Fishes cannot live in water which, either by boiling or exhaustion, has been entirely deprived of air.

The habitudes of other gaseous substances with water will be more advantageously illustrated, when those substances are under consideration.

184. *Experimental Proof of the Presence of Air in Water.*

Water exposed to the action of an air pump, or otherwise subjected to exhaustion, becomes replete with air-bubbles.

Of the Moisture in Air.

Air is not more invariably *attendant* upon water than water is upon air; nor is the air in water more necessary to fishes, than the water in the air to animals and vegetables.

The well known deleterious influence of the winds which blow from the African deserts, arises probably from their aridity. The desiccating power of air is directly as its temperature, and inversely as the quantity of moisture previously associated with it.

There is a certain proportion of moisture, relatively to the temperature, which is most favorable to our comfort. If the moisture be increased without raising the temperature, or the temperature be increased without an accession of moisture, we are incommoded. In the one case, the skin becomes unpleasantly dry; in the other, the air is too much encumbered with aqueous vapour, to allow perspiration, whether sensible or insensible, to proceed with sufficient freedom.

Stove rooms are oppressive on account of the too great aridity of the air in them; and hence the well known remedy of a basin of water, placed upon the stove to furnish moisture by its evaporation.

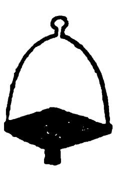
Hygrometric Process of Dalton.—The dew which is observable on vessels containing cold water, in warm weather especially, arises from the condensation of the aqueous vapour in the air.

According to Mr. Dalton, the less the degree of cold requisite to produce this phenomenon, the greater the quantity of moisture in the air. Hence, by ascertaining the highest temperature at which the water is capable of producing the condensation, the quantity of moisture may be known from a table which he has constructed.

Daniell's Hygrometer.—Mr. Daniell has contrived an hygrometer upon the principle thus suggested by Dalton. Vaporization is ingeniously applied to *produce* cold in one bulb of the instrument, in consequence of the cold produced by the evaporation of ether in another bulb, as in the cryophorus, 124. Two thermometers accompany the instrument, one within the bulb refrigerated by the vaporization; the other so situated as to indicate the temperature of the atmosphere. As the quantity of aqueous vapour in the air diminishes, the depression of temperature necessary to the precipitation of moisture on the refrigerated bulb increases. The extent of the depression is ascertained by the thermometers, the quantity of water in the air by reference to a table.

Organic Sensibility to Moisture of the Beard of the Wild Oat.—Hygrometers have been made which are dependent upon the contraction or dilatation which catgut, whalebone, and other substances of a like nature undergo, in proportion to the quantity of moisture in the air. Among instruments of this kind, that formed by means of the beard of the wild oat is pre-eminent for its susceptibility to the influence of moisture. Breathing on it causes the index to be moved instantaneously. The indications of hygrometers thus constructed are not referrible to any standard, agreeably to which a comparison can be made between the dryness of the air in different places at the same time, or in the same place at different times.

Hygrometric Process by means of a Balance.—It may be presumed that the quantity of moisture in the air is inversely as the weight of water which will in a given time evaporate from a moist surface. If this presumption be correct, the little square dish here represented may, with the aid of a delicate scale beam, be used as an hygrometer. If it be suspended to the balance, and equipoised while containing a little water, the counter-weight will in a few minutes preponderate, in consequence of the loss by evaporation.



The loss of weight within any known period being determined, the evaporating power of the air will be as the loss of weight; but as the evaporation is more or less rapid in proportion as there may be more or less agitation, it will not be right to infer that the quantity of aqueous vapour in the atmosphere is inversely as the rate of evaporation, unless the process were uninfluenced by the wind.

Compounds of Chlorine with Water.

Hydrate of Chlorine.—Berzelius observes that chlorine furnishes the only instance of an elementary substance capable of entering into combination with water. I allude here to a crystalline compound formed on passing the gas through that liquid at a temperature below 40° F. The hydrate thus formed is capable of being sublimed from one part of the containing vessel to another, in consequence of a slight diversity of temperature. It consists of one volume of chlorine, and twenty volumes of aqueous vapour.

Solution of Chlorine in Water.—Berzelius alleges that, in order to obtain a saturated solution of chlorine in water, it is necessary, in the first instance, to expel from the latter all the atmospheric air.

He does not consider that water will hold this principle simply in a state of solution, but that muriatic acid is formed by the union of chlorine with the hydrogen of the water; while its oxygen, combining either with chlorine or water, generates chlorous acid, or deutoxide of hydrogen.

These substances, he believes, are formed only in small quantities at first; yet it is from these that the extrication of oxygen gas is effected in the solar rays, and that oxygen is imparted to colouring matters bleached by the operation of this liquid. The muriatic acid, created at the same time, is prone to injure fabrics subjected to it; and hence, in bleaching, solutions of the chloride of lime or of the fixed alkalies are
These are by Berzelius considered as chlorites, consisting of cl
and the oxybase employed, whether lime, potash, or sod

Of the Deutoxide or Bioxide of Hydrogen, or Oxygenated Water.

In 1818, Thenard discovered that water might be made to receive an additional quantity of oxygen, by dissolving deutoxide of barium in liquid muriatic acid, precipitating the baryta by sulphuric acid, and the chlorine by silver.

Properties.—The bioxide of hydrogen is as liquid, and as devoid of colour as water. It is nearly inodorous, whitens the tongue, inspissates the saliva, and tastes like some metallic solutions. Applied to the skin, it creates a smarting sensation, more durable in some persons than in others. Its specific gravity is 1.452. Hence, when poured into water, it descends through it like syrup, but is dissolved by agitation.

As it is less easy to vaporize than water, it may be separated from that liquid, by exposure in vacuo over sulphuric acid (122). In its most concentrated form, it has not been congealed by any degree of cold to which it has been subjected.

The most interesting property of this substance is that of giving off oxygen explosively, on being brought into contact with substances which do not unite with either of its ingredients. Thus it explodes by contact with finely divided silver, platinum or gold, and still more actively with oxide of silver or peroxide of lead.

The difficulty of explaining these phenomena has already been noticed. See the article on the states in which caloric exists in nature, page 122.

When mingled with the mineral acids, its liability to decomposition is diminished.

If exposed to heat in its most concentrated state, a few grains create a violent explosion. When, by dilution with 20 parts of water and exposure to heat, it loses all the oxygen which it holds beyond the quantity necessary to the composition of water, as much oxygen is found to be evolved as the hydrogen in the residual water retains. Hence it is generally supposed to consist of one atom of hydrogen and two of oxygen.

Remarks on Nomenclature.

I shall here, as in some other instances, quote from my letter on the nomenclature of Berzelius, such appropriate suggestions, as the student who has accompanied me thus far ought to be capable of understanding.

In common with other eminent chemists, Berzelius has distinguished acids in which oxygen is the electro-negative principle, as ***oxacids***, and those in which hydrogen is a prominent ingredient as ***hydracids***. If we look for the word radical in the table of contents of his invaluable Treatise, we are referred to p. 218, vol. 1st, where we find the following definition, "*the combustible body contained in an acid, or in a salifiable base, is called the radical of the acid, or of the base.*" In the second vol. page 163, he defines hydracids to be "those acids which contain an electro-negative body combined with hydrogen;" and in the next page it is stated, that "hydracids are divided into those which have a simple radical, and those which have a compound radical. The second only comprises those formed with cyanogen and sulphocyanogen." Again, in the next paragraph, "no radical is known that gives more than one acid with hydrogen, although sulphur and iodine are capable of combining with it in many proportions. If at any future day more numerous degrees of acidification with hydrogen should be discovered, their denomination might be founded on the same principles as those of oxacids." Consistently with these quotations, all the electro-negative elements forming acids with hydrogen are radicals, and of course, by his own definition, combustibles; while hydrogen is made to rank with oxygen as an acidifying principle, and consequently is neither a radical nor a combustible. Yet page 189, vol. 2d, in explaining the reaction of fluoboric acid with water, in which case fluorine unites both with hydrogen and boron, it is mentioned as one instance among others in which fluorine combines with ***two combustibles***.

I am of opinion that the employment of the word hydracid, as co-ordinate with oxacid, must tend to convey that erroneous idea, with which, in opposition to his own definition, the author seems to have been imbued, that hydrogen in the one class, plays the same part as oxygen in the other. But in reality, the former is eminently a combustible, and of course the radical by his own definition.

Dr. Thomson, in his system, does not recognise any class of acids under the appellation of hydracids, but, with greater propriety as I conceive, places them under names indicating their electro-negative principles. Thus he arranges them as oxygen acids, chlorine acids, bromine acids, iodine acids, fluorine acids, cyanogen acids, sulphur acids, selenium acids, and tellurium acids. These appellations might, I think, be advantageously abbreviated into oxacids, chloracids, bromacids, iodacids, fluacids, cyanacids, sulphacids, selenacids, telluracids.

I had formed my opinions on this subject before I was aware that Dr. Thomson had resorted to this classification.

As respects the acids individually, I conceive that it would be preferable, if the syllable indicating the more electro-negative element had precedency in all, as it has in some cases. The word hydrofluoric does not harmonize with fluoboric, fluosilicic, fluochromic, fluomolybdic, &c. Fluorine being in each compound the electro-negative principle, the syllables, indicating its presence, should in each name occupy the same station. These remarks will apply in the case of acids formed with hydrogen by all principles which are more electro-negative. Hence we should use the terms chlorohydric, bromohydric, iodohydric, fluohydric, cyanhydric, instead of hydrochloric, hydrobromic, hydriodic, hydrofluoric, hydrocyanic.

These opinions, conceived during the preceding summer, were published by me in the Journal of Pharmacy for October, 1833. Since then I find that, in the late edition of his Traité, Thenard has actually employed the appellations above recommended.

As by the British chemists the objectionable words have not been definitively adopted, the appellations muriatic and prussic being still much employed, it may not be inconvenient to them to introduce those which are recommended by consistency. In accordance with the premises, the acids formed with hydrogen by sulphur, selenium, and tellurium, would be called severally sulphydric, selenhydric, and telluhydric acid. Compounds formed by the union of the acids, thus designated, with the bases severally generated by the same electro-negative principles, would be called sulphydrates, selenhydrates, and telluhydrates, which are the names given to these compounds in the Berzelian nomenclature. Influenced by the analogy, a student would expect the electro-negative ingredient of a sulphydrate to be sulphydric acid, not a sulphide. The terminating syllable of this word, by its associations, can only convey the conception of an electro-positive compound.

COMPOUND OF HYDROGEN WITH CHLORINE.

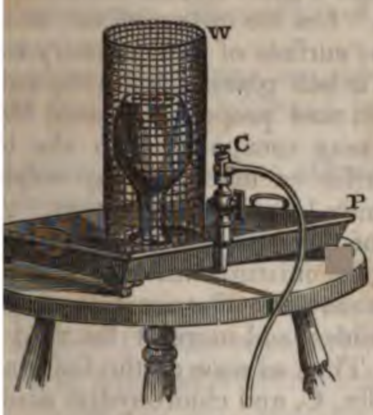
Of Chlorohydric or Muriatic Acid Gas.

When hydrogen and chlorine are mixed in equal volumes they combine spontaneously. In the dark, or where the light is feeble, the union is slowly accomplished, but, in the solar rays, takes place explosively. According to Silliman, the direct rays of the sun are not necessary to produce the result. The mixture may also be exploded by the electric spark, or by contact with any ignited matter. However the union may be effected, chlorohydric or muriatic acid gas is produced, without any reduction of volume if no water be present.

Synthesis of Chlorohydric Acid Gas.

In order to demonstrate the ratio in which chlorine and hydrogen combine, it is only necessary to introduce and ignite in the volumescope over water, equal measures of each gas. If they be pure there will be a complete condensation. The experiment is conducted precisely as in the case of oxygen and hydrogen, (177), excepting that chlorine is substituted for oxygen in a double proportion.

85. *Explosive Reaction of Hydrogen with Chlorine, under the Influence of the Solar Rays.*



A flask is half filled with chlorine over the pneumatic cistern in the usual way, and then transferred to the pan P, so as to have its orifice exactly over that of a pipe which, at the other end, communicates with the cock C, to which is annexed a flexible pipe extending to a self-regulating reservoir of hydrogen, 173.

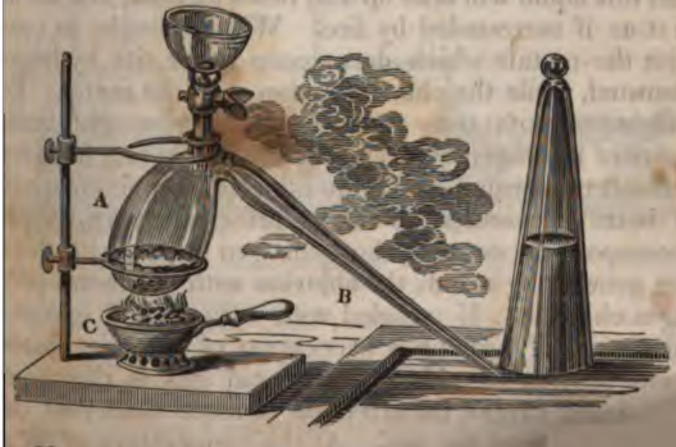
The flask is surrounded by a wire gauze, W, and just before the explosion is desired, hydrogen from the reservoir is allowed to occupy that portion of the cavity which was previously cupied by the chlorine. It should be understood that the pan, during peration, retains a sufficient stratum of water to cover the mouth of lask, and that this is occupied with the same liquid in part until it is aced by the hydrogen.

e preliminary arrangements being made, a mirror must be placed in ation to receive the solar rays without passing through window glass, to reflect them upon the flask. The result is an explosion, from the ts of which the spectators are protected by the wire gauze.

must be obvious that this experiment can only succeed when the sun obscured.

should be understood that the condensation arises altogether from the rption of the gas by the water.

86. *Preparation of Chlorohydric or Muriatic Acid Gas.*



Into a tubulated retort, introduce about as much chloride of sodium (common salt) as will occupy nearly one-third of the body, A. Lute a glass funnel, furnished with a cock, into the tubulure. Let the orifice of the beak, B, be so depressed below the surface of the mercury in the cistern, as to be under a bell glass, filled with and inverted over the mercury, and properly situated for receiving any gas which may escape through the beak. Prepare about three-fourths as much strong sulphuric acid by weight as there may be salt in the retort. After pouring about one-third of the acid into the retort, close the cock of the funnel: the mixture will rise in a foam, and a portion of gaseous matter will pass into the bell. As soon as the foam subsides, add more of the acid until the whole is introduced. Then as soon as the foam again subsides, apply the chauffer, C, and chlorohydric acid gas will continue to be copiously evolved.

Rationale.—The water combined with the sulphuric acid is decomposed; its oxygen unites with the sodium, forming soda, with which the sulphuric acid combines, forming sulphate of soda. The hydrogen of the water and the chlorine escape as chlorohydric acid gas.

Properties.—Chlorohydric acid has all the attributes of a gas. It is colourless, and, although less active than chlorine gas, is to the organs of respiration intolerably irritating, and if not very dilute deleterious to life. On escaping into the air, it produces white fumes, from its meeting with moisture. Its affinity for water is so great, that this liquid will take up 420 times its bulk, and ice melts in it as if surrounded by fire. When brought in contact with the metals which decompose water, its hydrogen is liberated, while the chlorine unites with the metal. Equal weights of potassium separate the same weights and volumes of hydrogen from chlorohydric acid and from water, a result conformable with the inferred atomic composition of both. Presented to the metallic oxides, a reciprocal decomposition ensues; the hydrogen unites with the oxygen generating water, the chlorine with the metal producing a chloride. If mingled with oxygen and exposed to the action of heat or a succession of electric sparks, small portion of chlorohydric acid gas is decomposed. This result cannot be extended to more than $\frac{1}{35}$th of t whole volume of the gas. At the temperature of 50°, a under a pressure of forty atmospheres, it becomes a colourless liquid.

Its specific gravity is 1.2694, a mean between that of its constituents. The weight of 100 cubic inches is 39.36 grains.

One atom of chlorine, equivalent	36
And one atom of hydrogen, equivalent	1
Constitute one atom of chlorohydric acid gas, equivalent	37

187. *Experimental Illustrations.*

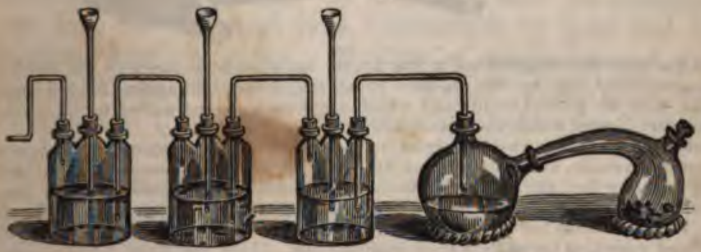
Equal volumes of hydrogen and chlorine, being mixed and subjected to the solar rays or galvanic ignition, explode and form chlorohydric acid gas.

Gas collected over mercury in tall jars. Water, coloured by litmus, being introduced, rapidly changes to a red colour, and causes the disappearance of the gas. Same effect produced by ice, which is rapidly melted.

Preparation of Liquid Chlorohydric or Muriatic Acid.

It may be obtained by saturating water with the gas in Woulfe's apparatus. (See the following figure.) The solution is nearly pure in all the receptacles excepting the first.

188. *Woulfe's Apparatus.*

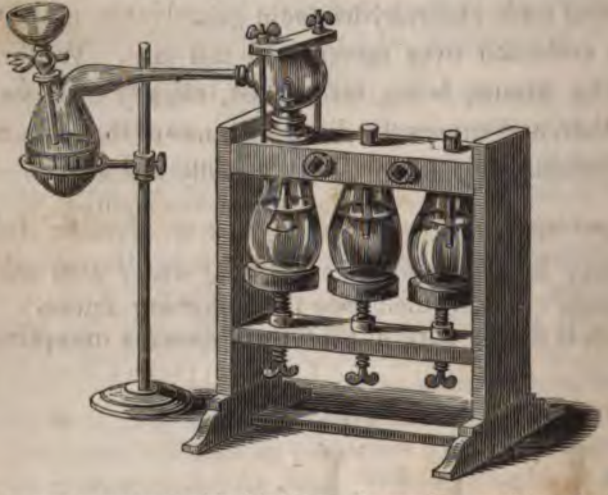


This figure is intended to convey an idea of Woulfe's apparatus in an improved form. The gas evolved in the retort first passes into the globe, where any vapour which may accompany it condenses.

It then proceeds along the tube which establishes a communication with the bottle next to the globe. As the mouth of this tube which is within the bottle, is below the surface of the liquid placed there to absorb it, the gas has to bubble up through the liquid, so as to promote its own absorption by the agitation thus induced. It then rises above the surface of the liquid, where a further absorption takes place. The excess of gas, beyond the quantity absorbed by the liquid in the first bottle, passes, by means of the connecting tube, to the second bottle, and what is not there absorbed, reaches the third bottle, where the process proceeds as in the first two. Should any of the gas escape the whole series, it may, by lengthening the last tube, be conducted under a bell glass filled with water on the shelf of the hydro-pneumatic cistern, so as not to annoy the operator. But this never takes place in the case of chlorohydric acid gas, until the water is nearly saturated.

Supposing the extrication of gas to cease before the liquid in the first bottle is saturated, the absorption continuing, the liquid in the second bottle might be transferred to the first, in consequence of the rarefaction of the residual gas rendering it incompetent to resist the atmospheric pressure. In like manner the contents of the third bottle might be transferred to the second. To prevent these inconveniences, there is in each bottle a straight tube fastened air-tight into an intermediate neck, and descending into the liquid. By these means an adequate pressure is opposed to the escape of the gas, and yet any diminution of pressure, arising from absorption, will be compensated by the ingress of atmospheric air, ere the liquid can be drawn over from the next bottle. To prevent absorption from the first bottle into the globe, it is best to use, for the introduction of the acid, a trumpet-mouthed tube of small bore, passing through and luted into the tubulure by a cork with lead and a gum elastic bandage, and terminating in a small orifice near the bottom of the retort inside.

189. *Vases tightened by Screws, substituted for Woulfe's Bottles.*



In the apparatus represented in this figure, the vessels, containing the liquid to be impregnated, are, by the pressure of screws, made tight against leaden plates, which they are ground to fit, and which are cemented and nailed to the wooden cross-piece, under which the vessels are situated.

Into the cross-piece two horizontal holes are bored, from a common orifice, so as to enter, severally, other holes bored vertically, of which one communicates internally with the first, the other with the second vessel. The external orifice being closed by a screw, a communication is established between the cavities of the vessels, which obviates the necessity of tubes. The second vessel communicates with the third vessel, in the same way as with the first.

The hole over either vessel, which communicates with the inside of the preceding vessel, is furnished with a tube passing downwards a few inches, so as to enter any contained liquid. The tube, thus immersed in the first vessel, rises into and communicates with the cavity of the globe. This globe is pressed by screws against a leaden plate, which it is ground to fit, so as to make an air tight juncture, in the same way as already described in the case of the vessels below the cross-piece.

Hence the first tube establishes a communication between the globe and the liquid in the first vessel, below the surface of which its trumpet-shaped orifice reaches. The second tube, communicating, by means of the perforations made in the wood, with the cavity of the first vessel, descends into the liquid contained in

econd vessel. The third tube, in like manner communicating with the ca-
of the second vessel, descends into the liquid of the third vessel.

e gas, extricated from the retort, passes into the receiver, where it deposites
ondensable matter, and proceeds down the tube into the first vessel. What-
gas is not there absorbed, proceeds, through the perforations in the wood, to
ube in the second vessel, escaping from that into the liquid. The excess of
eyond what is there taken up, will reach the third vessel from the second, as
ched this from the first.

may be proper to mention that the perforations in the wood are charred by
s of a red-hot iron, and while hot soaked with bees wax. By these means,
are rendered impervious to any gas.

the top of the wooden cross-piece, there are some holes which are represented
closed with corks. These are for the introduction of safety tubes, as in the
ulfe's bottles described in the preceding article, when they may be deemed
ssary.

ocess for obtaining Liquid Chlorohydric Acid by simple Distillation.

Liquid chlorohydric acid may be obtained by distilling
olution of chloride of sodium in water with sulphuric
d. In this way there is no need of an apparatus for
moting absorption, as described in the preceding arti-
. The acid comes over and condenses in union with
requisite quantity of water.

Properties of the Liquid Acid.—When concentrated
produces suffocating fumes from the escape of gas.
hen pure, it is colourless, though usually straw-coloured
m the presence of a minute portion of iron. Chlo-
ydric acid *can be said to combine with those alkalies,*
ths, and oxides only, which form with it soluble salts. It
doubtful whether, when presented to such compounds,
is not always resolved into a chloride and water.
rzelius conceives that it cannot exist as an acid in
mbination with oxides. It is certain that its combina-
ns are, for the most part, convertible by heat and de-
cation into chlorides. Muriate of magnesia and mu-
te of alumina are exceptions. I shall notice this ques-
n again in treating of the reaction of chlorine with the
tals of the earths and alkalies.

Dr. Thomson informs us that the strongest liquid acid
ich he could obtain, consisted of one atom of acid, equi-
ent 37, united with six atoms of water, which being
ivalent to 54, the proportion of acid to water by
ight was as those numbers, or nearly as 2 to 3.

190. *Experimental Illustrations.*

Liquid chlorohydric acid exhibited; also its reaction
th other bodies.

Of the Old Theory of the Nature of Chlorine and Chlorohydric Acid.

Chlorohydric acid was deemed to be a compound of oxygen with some unknown radical. When distilled from red oxide of lead, or black oxide of manganese, it was supposed to combine with a portion of the oxygen of those oxides, forming oxygenated muriatic acid, the name then given to chlorine. To the oxygen thus imagined to exist in it, the activity of chlorine, as a supporter of combustion and as a solvent of metals, was ascribed. It has since been proved that neither carbon nor the metals are oxidized when intensely ignited in dry chlorine. The metals are converted into chlorides, while the carbon undergoes no change. Chloride of sulphur and bichloride of phosphorus, which result from saturating these substances with dry chlorine, are devoid of acidity; but the addition of water converts the one into muriatic and phosphorous acid, the other into muriatic and hyposulphurous acid.

If chlorine be muriatic acid oxygenated, the discovery of the protoxide of chlorine, and of chlorous, chloric, and oxychloric acids must establish this anomaly, that the radical of muriatic acid, by successive additions of the same acidifying principle, gains, loses, and regains acidity, forming first an acid, then two oxides, and finally three acids. I have said it forms *two* oxides, because chlorine must be deemed an oxide, having no acid properties.

It has been stated, page 200, that Thenard oxygenated the water in liquid muriatic acid; yet this did not convert it into a solution of chlorine.

Agreeably to the doctrine now universally sanctioned by chemists, chlorohydric acid, consisting of chlorine and hydrogen, is deprived of hydrogen in all those processes by which it was formerly supposed to be oxygenated.

COMPOUNDS OF HYDROGEN WITH BROMINE AND IODINE.

Neither with bromine nor iodine does hydrogen directly combine, yet phosphorus combines with them spontaneously. The resulting compounds have upon water an effect quite analogous to that produced by the chlorides of phosphorus; producing phosphoric acid by a union between the phosphorus and oxygen, and bromohydric or iodohydric acid by a combination of the hydrogen of the water with bromine or iodine.

Of Bromohydric Acid.

in bromohydric acid, Berzelius recommends that phosphorus
ılaced in contact with bromine under water. The resulting bro-
solved into phosphoric acid and bromohydric acid gas. The
be collected over mercury, or made to produce liquid bromohy-
ıy union with water, exactly by the same means as have been
in the case of chlorohydric acid, which the bromohydric acid
nbles. Bromohydric acid is a colourless gas, in smell similar
rdric acid. It has a specific gravity of 2.7353. When brought
with the air it produces thick fumes. It is decomposed in pass-
h a tube heated red-hot. It is composed of one atom of hydro-
ıe of bromine.

Of Iodohydric Acid.

ıg to Berzelius, in order to procure iodohydric acid, nine parts
ıd one of phosphorus should be placed in contact at the bottom
r small matrass, and protected from the air by powdered glass.
ıosphorus is formed, which is resolved into phosphoric acid and
acid gas by the gradual affusion of a small quantity of water.
annot be collected over water or mercury, as it acts on the
ı absorbed by the other. Hence it must be collected in bot-
ans of tubes descending through their orifices to their bottoms,
nalogous to the mode, already illustrated on a large scale, for
hlorine, page 160. This process is even more practicable in
point; since iodohydric acid is the heaviest gas known, having
ravity of 4.3854, or more than four times as great as that of
c air. In composition and general properties it resembles chlo-
ıd bromohydric acid.

ıpound of hydrogen with fluorine, forming the acid of fluor spar
ic acid, will be deferred for consideration, until boron and si-
been treated of.

ric Appellation for the Acids called by some distinguished Chemists Hydracids.

is a striking analogy between the bodies, called halogen by
which makes it advantageous to designate them by one epithet,
ıght it expedient to use for that purpose, the term which he has
although not approving of the grounds on which it was con-
him. In like manner, the acids formed by the halogen bodies
ıgen, have common properties, which renders it convenient to
ıydracids, agreeably to the practice of the great chemist above
of Thenard, and of other distinguished men. But, believing
that term to involve error and inconsistency, as I have endea-
show, page 201, I will hazard a word for the purpose in ques-
ated from *halogen* and *hydrogen*. Under the generic appella-
lohydric acids, I would place chlorohydric, bromohydric,
fluohydric, cyanohydric, and sulphocyanohydric acids. Of
class will not comprise all that hav ... lled hydracids,
ch are sulphydric, selenhydric, and t ... and water,
r, however, is placed among the
an oxacid than as a h
acids last mentioned.

be designated as ***amphydric acids***, consistently with the course which I have adopted, of using the term ***amphigen*** to distinguish the four elements so called by Berzelius.

COMPOUNDS OF HYDROGEN WITH SULPHUR.

It appears probable that hydrogen and sulphur may combine in various proportions. Only two compounds, however, have been sufficiently distinguished, to be worthy of a place in this work. One of these is a definite compound of hydrogen and sulphur, containing an atom of each, and has hitherto been called sulphuretted hydrogen, especially by the British chemists. The other contains one atom of hydrogen with a plurality of atoms of sulphur, which, according to Thenard, may extend to the proportions of four, six, or eight atoms to one. To this he has accordingly given the name of polysulphuret of hydrogen.

Pursuant to the nomenclature of Berzelius, all the electro-negative compounds of sulphur are called sulphides, and are designated by attaching, as an adjective, their radical, with the last syllable changed into *ique* in French, or *ic* in English; as, for instance, sulphuretted hydrogen is called by him in French, *sulphide hydrique*, which in English is rendered by *hydric sulphide*. This gas has by some chemists, especially the French, been called hydrosulphuric acid, by analogy with hydrochloric acid. The term *hydrosulphuric* is objectionable from its conveying the idea of aqueous sulphuric acid; *hydro* being used to imply the presence or influence of water. I have already pointed out the inconsistency of designating some acids by giving precedence to the syllables representing their radical, as in hydrochloric, hydriodic; while in others, the syllable indicative of their electro-negative ingredient has the precedence, as in fluosilicic, fluoboric, chlorocarbonic, and chlorocyanic. If sulphuretted hydrogen is to receive a new name, I would prefer to call it *sulphydric acid*, as already suggested.

Of Sulphydric Acid or Sulphuretted Hydrogen.

Few persons are unacquainted with the unpleasant odour which results from the washings of a gun barrel, made foul by the explosion of gunpowder, or that produced by putrid eggs. This odour arises from a compound consisting of one atom of hydrogen and one atom ıur. The celebrated sulphur springs of Virginia bted for their odour and mainly for their efficacy ompound, to which the celebrated Thenard has e name of sulphydric acid. No doubt he was acy the same views as myself, when, without any ge of his opinions, I published my impressions on ect in the Journal of Pharmacy for October, 1833.

ration.—This gas is copiously evolved by the ref diluted sulphuric acid with sulphuret of iron. In have a supply of it at command, it is only necessubstitute this last mentioned substance for zinc elf-regulating apparatus employed for hydrogen described, article 172.

is absorbed by water and gradually decomposed ury, Berzelius recommends that it should be rever brine. Its purity is demonstrated by its comsorption by a solution of caustic potash, and by its lering lime-water milky.

so advises that the gas should be passed through s otherwise it is liable to be contaminated by the ng materials. When the acid is sufficiently diıe action in the apparatus above referred to is so that I am confident from my experience that the ıes over sufficiently pure for ordinary purposes.

venient Method of Impregnating Liquids with Sulphydric Acid.

Suppose the little flask, F, to contain the liquid to be impregnated, and the flexible pipe, one end of which is inserted into the orifice of the flask, to proceed from a self-regulating reservoir of sulphydric acid: it must be evident that the gas, flowing into the cavity of the flask from the orifice of the pipe, must enter the solution. If not absorbed as rapidly as it may be yielded, the excess must bubble up through the solution; the cork being meanwhile loosened to allow the atmospheric air to escape. The expulsion of the atmospheric air having been completed, and the cork inserted into the neck of the flask, so as to prevent the gas from escaping, it will continue to enter the flask as fast as absorbed. But if it be generated in the reservoir more rapidly than the solution can absorb it, must remain in the reservoir, and contribute to depress the acid the bell glass, as to diminish the quantity of the sulphuret on which it can act. Finally, when the solution becomes saturated, the gas generated in the bell must fill it, and thus, by usurping the place of the acid, cause its reaction with the sulphuret to be suspended.

Properties.—Sulphydric acid is a permanent gas with the odour of rotten eggs, absorbable by water, inflammable and explosive, forming, by combustion with air or oxygen gas, water, and a mixture of sulphurous and sulphuric acids. Its aqueous solution reddens litmus. Metals are tarnished by it, especially preparations of lead, of which it is a test, and by which it may be detected. It is evolved from privies, blackening the ceruse or carbonate of lead in paint. It may be decomposed by various substances, having some affinity for one or both of its constituents, as for instance, by chlorine, potássium, sodium, sulphurous acid, and ignited carbon; also by successive electric explosions.

Sulphydric acid decomposes all metallic solutions, except those of iron, nickel, cobalt, manganese, titanium, and molybdenum, in consequence of the attraction between hydrogen and either oxygen or chlorine, and between the metals and sulphur. Metals which in the metallic state yield hydrogen during their reaction with diluted sulphuric or muriatic acid, afford sulphydric acid, when subjected to those acids in the state of a sulphide or sulphuret. According to Berzelius, some sulphides act as acids, others as bases, and unite with each other in a manner analogous to that in which the oxacids and oxybases combine. The resulting compounds he calls sulpho-salts. Some sulphides are liable to be reduced by exposure to pure hydrogen in a way analogous to that in which oxides are decomposed by the same agent. But the number of sulphides which may be thus decomposed is much smaller. Atmospheric air is said to be rendered deleterious to life by the addition of $\frac{1}{250}$th of this gas.

At the temperature of 50° F., and under a pressure of 17 atmospheres, sulphydric acid becomes a colourless liquid more fluid even than sulphuric ether. It is alleged that a single cubic inch of the gas, liberated in a large chamber, will in every part be productive of its characteristic unpleasant odour. A current of the gas directed upon the tongue causes an astringent, acid, and bitter taste. The specific gravity of sulphydric acid is 1.1782, that of atmospheric air being 1. It is slowly decomposed by nitric oxide, and by sulphurous acid when moist. Nitric acid reacts with it explosively. With sulphurous acid when dry it does not react; but, water being present, condensation ensues with a deposition of sulphur, and, according to Thomson, the production of a peculiar acid. At the temperature of 50° F., water takes up three times its bulk of sulphydric acid, which may be entirely expelled by a boiling heat. The aqueous solution reddens litmus, and becomes turbid after some time by exposure to the air, with the oxygen of which the hydrogen of the gas combines, while the sulphur precipitates. It has already been stated that water impregnated with sulphydric acid exists in many natural springs, which are much frequented by invalids.

The celebrated white sulphur, salt sulphur, and red sulphur springs of Virginia, are of this nature. They appear particularly efficacious as remedies for bilious disorders, and in cutaneous diseases.

The red sulphur springs are thought to be peculiarly useful in some pulmonary complaints, and have a surprising and unaccountable influence in lowering the frequency and force of the pulse.

192. *Experimental Illustrations.*

Method of extricating sulphydric acid gas by means of a self-regulating reservoir exhibited; also, the impregnation of water with it. Effects of its aqueous solution on litmus, and on various metallic solutions. Characters written with dissolved acetate of lead are blackened by exposure to the gas, or its aqueous solution. Its inflammation by nitric acid.

193. *Sympathetic Picture.*

The original of this figure was drawn of a gigantic size in acetate of lead, and was invisible at a little distance, until a jet of sulphuretted hydrogen was directed upon it. The image then appeared by the waving of the pipe from which the gas flowed, as if it were the wand of a magician.

If the acetate has had time to become dry, the experiment will not succeed without restoring a due degree of moisture. This object is best accomplished by passing a wet sponge over the back of the sheet on which the figure has been drawn.

Rationale.—The acetate of lead consists of acetic acid and oxide of lead. The oxygen of the oxide unites with the hydrogen of the gas, while the sulphur and lead form a sulphuret, to which the blackness of the picture is due.

Of the Polysulphide of Hydrogen.

There are various compounds formed by sulphur with metals, some of which are soluble; as for instance the compound formed by boiling it with lime. This compound has been called a persulphuret of calcium. I would call it a persulphide. Scheele ascertained that on pouring into a diluted acid a persulphuret, such as that to which I have alluded, an oily looking liquid was precipitated, which subsequently received the name of bisulphuretted hydrogen. Thenard designates this compound as the ***polysulphuret of hydrogen***, on account of the great and variable number of atoms of sulphur which enter into its composition. Moreover he alleges that it constitutes a compound analogous in its properties to the deutoxide of hydrogen; being like that mysterious combination decomposable by many substances for which it has no affinity. Even the presence of the persulphide employed in its production is incompatible with its existence, and hence the impossibility of forming it by pouring the acid into the solution. In that case an excess of the persulphide must inevitably be present.

He alleges that the polysulphuret (polysulphide) is always liquid at ordinary temperatures. Its colour is yellow, sometimes approaching a greenish-brown. It whitens the tongue when applied to it, as is the case upon making a similar application of deutoxide of hydrogen. The same effect is produced upon the skin. Litmus paper is bleached by it, more especially when it is diffused in muriatic acid. Sometimes it has the consistency of an essential oil, sometimes of a fat oil, according to the proportion of its constituents, which has already been stated to be variable. Its odour is peculiar and disagreeable, especially at the period when, having been recently formed, the supernatant liquid is decanted from it. Then also it affects the eyes painfully. Sooner or later it is resolved into its elements spontaneously. Charcoal, platinum, gold, iridium, and many other metals in the pulverulent form, cause the evolution of the hydrogen. Many metallic oxides have the same effect, some so actively as to cause a brisk effervescence. These results also ensue from contact with the deutoxide or bioxide of manganese, from magnesia, from silica, and above all from pulverized baryta, strontia, lime, potash, and soda. From some of the facts mentioned by Thenard, I infer that this substance may be of great service in bleaching.

COMPOUNDS OF HYDROGEN WITH SELENIUM AND TELLURIUM.

Of Selenhydric Acid, commonly called Selenuretted Hydrogen.

Selenhydric acid is supposed to consist of one atom of sulphur, and one atom of hydrogen. It may be obtained from the selenide of potassium or of iron, by the action of chlorohydric acid. It is a colourless gas, absorbable without change of colour by water which has been boiled. Water thus impregnated has an hepatic taste, reddens litmus paper, and if applied to the skin, stains it a brownish-red. The solution exposed to the air, by the oxidation of the hydrogen, becomes gradually turbid from the surface downwards, acquiring a reddish hue, and depositing selenium in light flocks. All metallic salts, even those of iron and zinc, when they are neutral, are precipitated by selenhydric acid. The precipitates are generally of a deep black colour, yet those of zinc, manganese, and cerium are flesh-coloured. By the oxidizement of the hydrogen in selenhydric acid, selenium is precipitated of a cinnabar-red colour on any moist body. This acid exercises upon the respiratory organs a violent action, which might easily become dangerous. It produces at first the odour of sulphydric acid, but soon after a prickling sensation in the membranes of the nostrils, which resembles that created by fluosilicic acid gas, but is more stimulating. Subsequently the eyes become red, and the sense of smell is paralyzed. A single bubble of the gas, received into the nose, caused such a paralysis of the olfactory nerves, as to create insensibility even to the fumes of the strongest ammonia. The power of detecting odours was not recovered before the expiration of five or six hours.

Thenard mentions that Berzelius, in consequence of inhaling selenhydric acid gas, was attacked by a cough so severe, that a blister was deemed necessary. The quantity inhaled was so minute as to give the impression, that, in its effects upon the human system, this gas is preeminently pernicious.

Of Telluhydric Acid, commonly called Telluretted Hydrogen.

When an alloy of tellurium with zinc or tin is exposed to the action of chlorohydric acid, telluhydric acid is evolved. It is a colourless gas which strongly resembles sulphydric acid in odour, and in its chemical and mechanical properties. It reddens litmus paper, dissolves in water, producing a colourless solution, which by exposure to the air becomes brown, in consequence of the oxidation of the hydrogen and precipitation of the tellurium. It is probably composed of one atom of hydrogen and one of tellurium.

SECTION II.

OF NITROGEN OR AZOTE.

In the gaseous state, it forms nearly four-fifths of the atmosphere in bulk. Its ponderable base is a principal element in animal substances. In vegetables, it is only occasionally found. It was called azote, from the Greek ζωη, life, and α, privative of. It was subsequently named nitrogen, azote being equally applicable to other gases which are destructive of life.

I regret that Thenard, instead of abandoning the use of this bad word, has lately endeavoured to give it a further hold on nomenclature, by using the words azotous and azotic, in lieu of nitrous and nitric.

Nitrogen is derived from the same Greek verb as oxygen, combined with the word nitre or nitric. Hence nitrogen signifies a capacity to produce nitre or nitric acid, as oxygen conveys the idea of a capacity to produce acids.

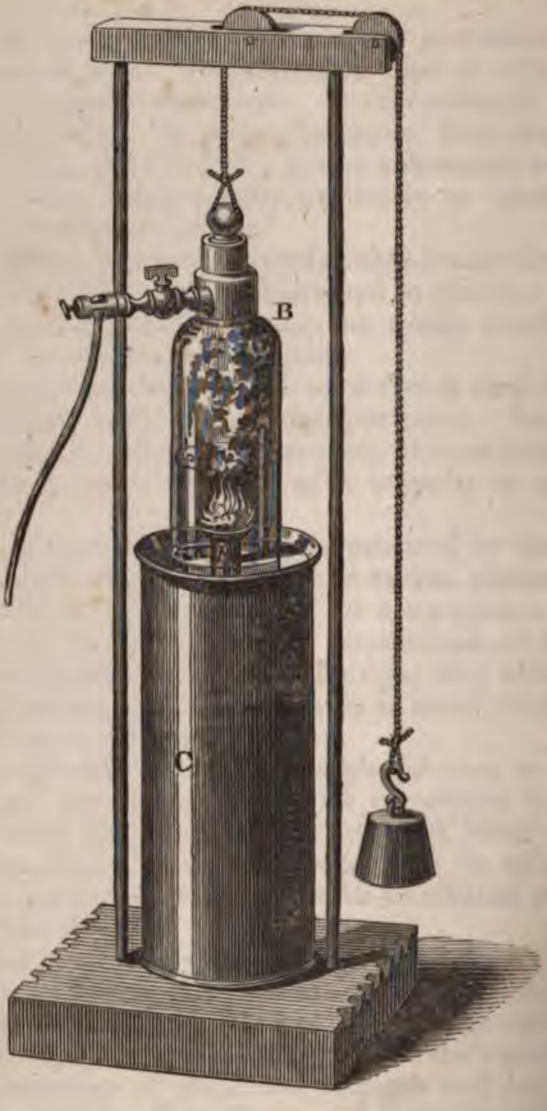
Preparation.—Nitrogen may be procured by the aid of any substance which will, in a close vessel, abstract oxygen from the included portion of the atmosphere; as, for instance, by the combustion of phosphorus, or by iron filings and sulphur moistened. This gas may also be obtained by heating muscular flesh in a retort with nitric acid very much diluted.

When obtained by means of phosphorus, a minute quantity of this substance remains in solution in the nitrogen; when extricated by the action of nitric acid, it contains a small portion of carbonic acid. In either case it may be purified by washing it with an alkaline solution, or with lime-water.

Another method of obtaining nitrogen gas is to pass chlorine through liquid ammonia. The chlorine unites with the hydrogen of the ammonia, while the nitrogen is liberated. Care must be taken to have the ammonia in excess, otherwise a chloride of nitrogen may be formed, which is capable of producing the most violent explosions.

When the chlorite of lime (bleaching salt) is mingled with muriate of ammonia and moistened, nitrogen is evolved.

Abstraction of Oxygen from Atmospheric Air by Phosphorus.

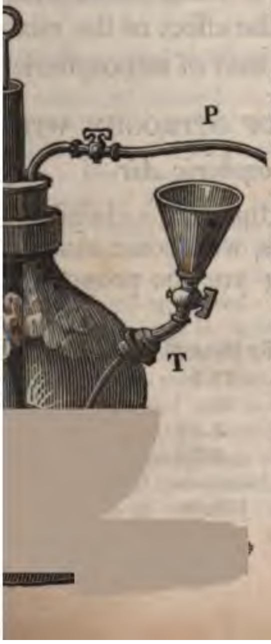


ratus for obtaining the Nitrogen from Atmospheric Air.

itus represented in the opposite engraving leaves the nitrogen is to be drawn easily from the containing vessel, in such l at such times as may be desirable. In its principal parts, fer from the gasometer for oxygen. See article 159. It is a pipe, *p*, concentric with the axis of the lower vessel, C, y a small copper cup. The pipe in question descends per- from the level of the brim of the vessel to the bottom; being a hole in the latter, so that, the bore being accessible from opper cup at the upper end may, when necessary, be touched of a red-hot iron rod, introduced through the pipe as already rticle 157.

vessel of the gasometer consists of a bell glass, B, suspended sing over a wooden gallows with suitable pulleys. The bell ted neck cemented into a brass cap, furnished with a female eiving a cock. To this cock a flexible lead pipe is attached screw. Upon the copper cup a sufficient quantity of phos- placed, and the lower vessel adequately supplied with water, is suspended within the lower vessel, as is usual with gasome- wed to descend about a third of its depth. Meanwhile, the be being open, the air is allowed to escape, so that the liquid thout the bell glass may be on a level. The cock being in closed, and the temperature of the phosphorus sufficiently e it take fire by touching the cup with the extremity of an viously reddened in the fire, a brilliant combustion ensues. declines, the iron, meanwhile kept in the fire, should be ced, in order to sustain the combustion till all the oxygen is

air in the bell glass is completely deoxidized, which may be yellow colour of the fumes, the residual nitrogen may be any recipient at pleasure, through the flexible pipe attached r that purpose, by depressing the bell in the water.



195. *Additional Means for obtaining Nitrogen.*

The apparatus, of which the annexed figure is a representation, may be used for the purpose of abstracting the oxygen from the air, by means of phosphorus.

The process is quite analogous to that already explained for the combustion of phosphorus in oxygen; excepting that the gun barrel is suspended from the cap, instead of entering from below, the situation of the cup for holding the phosphorus being varied so as to accord with the change. The bladder, B, affords room for the requisite expansion. The funnel and cock at T facilitates the introduction of water to expel the nitrogen as wanted; and the pipe P, and the cock associated with it, serve to control and direct the transfer of the nitrogen to the vessels in which its presence may be required.

Properties of Nitrogen Gas.—As a gas, it is distinguished by a comparative want of properties. It is lighter than oxygen gas, or atmospheric air. It supports neither life nor combustion, but is obviously a harmless ingredient in the air.

The affinity of nitrogen for caloric, compared with that which it displays for other substances, appears to be peculiarly great. Hence it is not liable, like hydrogen or oxygen, to enter into combination with other matter, so as to part with the caloric to which it owes its existence as a gas; and when under any circumstances it does enter into combination, it seems, more than almost any other substance, to carry caloric into combination with it; being, consequently, an ingredient in a majority of the most powerful fulminating compounds.

Nitrogen has been suspected by some chemists to be a compound, but is generally considered as an element. At the temperature of 60° F., 100 cubic inches weigh 30.1650 grains. Its specific gravity, comparatively with air, is 0.9727.

196. *Experimental Illustrations of the Properties of Nitrogen Gas.*

A portion of the nitrogen, obtained as above described being introduced into a bottle, extinguishes a candle flame when introduced into it; but being mixed with one-fourth of its bulk of oxygen gas, the effect of the mixture in supporting flame is similar to that of atmospheric air.

MECHANICAL COMPOUND OF NITROGEN WITH OXYGEN.

Of Atmospheric Air.

Atmospheric air is a mixture, not a chemical compound, of oxygen and nitrogen gas, with some moisture and carbonic acid. The following are the proportions given in Henry's Chemistry.

	By Measure.	By Weight.
Nitrogen gas	77.5	75.55
Oxygen gas	21.	23.32
Aqueous vapour	1.42	1.03
Carbonic acid	0.08	0.10
	100.00	100.00

The average of a great number of experiments, made th my eudiometers, makes the proportion of oxygen ı.66 in 100 of air.

In addition to these constituents, it is alleged that ere is a little chlorohydric acid in the atmosphere, in tuations in the neighbourhood of the sea; and hence it ises, probably, that animals far inland are much more nd of common salt, another compound of chlorine, than ose in regions bordering on the ocean.

It has been made a question whether the nitrogen and ygen of the air are not in a state of chemical combi- ıtion. I am of opinion that no other cause of union tween them exists than that which is known to produce e equable diffusion of heterogeneous gaseous particles nong each other, notwithstanding the difference of their ecific gravities.

In its qualities atmospheric air does not differ from a ixture. Oxygen, mingled with hydrogen in the same oportion in which it is mingled with nitrogen in the r, has been found to support animal life nearly as well.

The mechanical influence of the atmosphere, so far as appertains to chemistry, has been sufficiently illustrated. e pages 83 to 94. I have also treated of its capacity to old moisture, and to promote and produce cold by eva- ration. Some of the most accurate and easy methods analysing it, will be mentioned under the heads of nitric ide and phosphorus.

Eudiometrical Analysis of the Atmosphere.

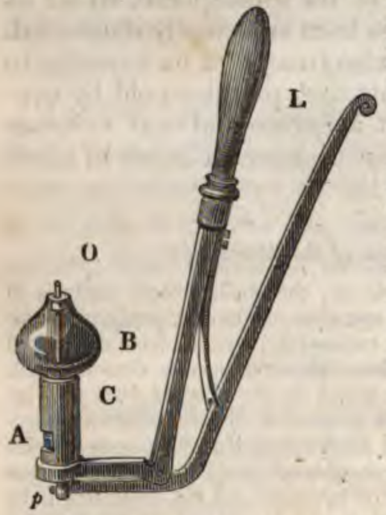
While on the subject of atmospheric air, the eudiometrical analysis of becomes necessarily an object of attention. I have already given an graving and description of a large eudiometer, which I have designated a volumescope. By means of that instrument it was demonstrated, at when the elements of water are mixed in the gaseous state and ig- ed, they will always combine in the proportion of two volumes of hy- ogen to one volume of oxygen. It follows that, if any gaseous mixture ntaining oxygen, and no other gas capable of combining with hydrogen oxygen, be ignited with an excess of hydrogen, all the oxygen will be ndensed into water, and may be estimated as equal to one-third of the sulting deficit. It follows also that, if, to a gaseous mixture containing drogen, and no other gas with which hydrogen or oxygen can combine, excess of oxygen be added and the mixture ignited, all the hydrogen ll be condensed, and will in quantity equal two-thirds of the deficit. ıus, if five volumes of atmospheric air and three of hydrogen be intro- ced into the volumescope and ignited, the eight volumes will be reduced rather less than five; of course a little more than three volumes will have been condensed, of which one-third is oxygen. In five volumes of atmospheric air, there is, therefore, somewhat more than one volume of oxygen. By the volumescope the excess cannot be accurately measured; but by other instruments which I have contrived, great accuracy is attainable. Before describing these, I will give engravings and descriptions of some implements for measuring gas, which must facilitate eudiometrical experiments, and which are also very useful in other pneumato-chemical operations. I am the more particular in describing my apparatus in this Compendium, that I may not be under the necessity of taking up time during my lectures with such descriptions.

197. *Piston Valve Volumeter.*

I have contrived some instruments for measuring gas with great accuracy. I call them volumeters to avoid circumlocution. They are of two kinds; one is filled by introducing it into any vessel containing the gas with which it is to be filled, over water or mercury; the gas is introduced into the other through an orifice, as is usual in the case of filling a common bottle over the pneumatic cistern. The following figure will convey a correct idea of one of them, which having a piston and a valve, I call the piston valve volumeter.

The lever, L, is attached by a hinge to a piston, *p*, which works inside of a chamber, C. The rod of this piston extends beyond the packing through the axis of the bulb, B, to the orifice, O, in its' apex, where it supports a valve, by which this orifice is kept close, so long as the pressure of the spring, acting on the lever L, is not counteracted by the hand of the operator.

Suppose that, while the bulb of this instrument, filled with water or mercury, is within a bell glass containing a gas, the lever be pressed towards the handle; the valve consequently is drawn back, so as to open the orifice in the apex of the bulb, and at the same time the piston descends below the aperture, A, in the chamber. The liquid in the bulb will now of course escape, and be replaced by gas, which is securely included, as soon as the pressure of the spring is allowed to push the piston beyond the lateral aperture in the chamber, and the valve into the orifice, O, in the apex of the bulb.

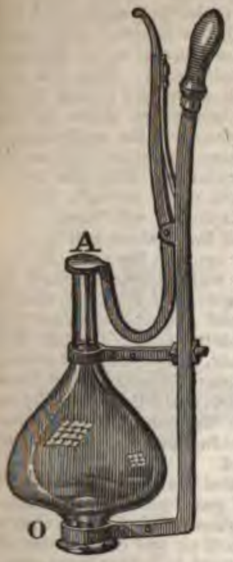


The gas, thus included, may be transferred to any vessel, inverted over mercury or water, by depressing the orifice of the bulb below that of the vessel, and moving the lever, L, so as to open the aperture, A, in the chamber, and the orifice of the bulb simultaneously.

The bulk of gas, included by this volumeter, will always be the same; but the quantity will be as the density of the gas into which it may be introduced when filled. Hence in order to measure a gas accurately, the liquid, whether water, or mercury, over which it may be confined, should be of the same height within as without. This is especially important in the case of mercury, which, being in weight to water as 13.6 to 1, affects the density of a gas materially; even when its surface, within the containing vessel, does not deviate sensibly from the level of its surface without.

To remove this source of inaccuracy I employ a small gauge, which communicates, through a cock in the neck of the bell, with the gas within. In this gauge any light liquid will answer, which is not absorbent of the gas. In the case of ammonia, liquid ammonia may be used; in the case of muriatic acid gas, the liquid acid. One of the gauges which I have used will be described in the Appendix, as attached to the mercurial sliding rod eudiometers. The other is simply an inverted glass syphon.

198. *Simple Valve Volumeter.*



Besides the lower orifice, O, by which it is filled with gas, the volumeter which this figure represents, has an orifice at its apex, A, closed by a valve attached to a lever. This lever is subjected to a spring, so as to receive the pressure requisite to keep the upper orifice shut, when no effort is made to open it.

When this volumeter is plunged below the surface of the water in a pneumatic cistern, the air being allowed to escape, and the valve then to shut itself under the water, on lifting the vessel it comes up full of the liquid, and will remain so, if the lower orifice be ever so little below the surface of the water in the cistern. Thus situated, it may be filled with hydrogen, proceeding by a tube from a self-regulating reservoir. If the apex, A, be then placed under any vessel, filled with water and inverted in the usual way, the gas will pass into it as soon as the valve is lifted.

Volumes of atmospheric air are taken by the same instrument, simply by lowering it into the water of the cistern, placing the apex under the vessel into which it is to be transferred, and lifting the valve: or preferably by filling it with water, and emptying it in some place out of doors, where the atmosphere may be supposed sufficiently pure, and afterwards transferring the air, thus obtained, by opening the valve, while the apex is within the vessel in which its presence is required. In this case, while carrying the volumeter forth and back, the lower orifice must be closed. This object is best effected by a piece of sheet metal, or a pane of glass.

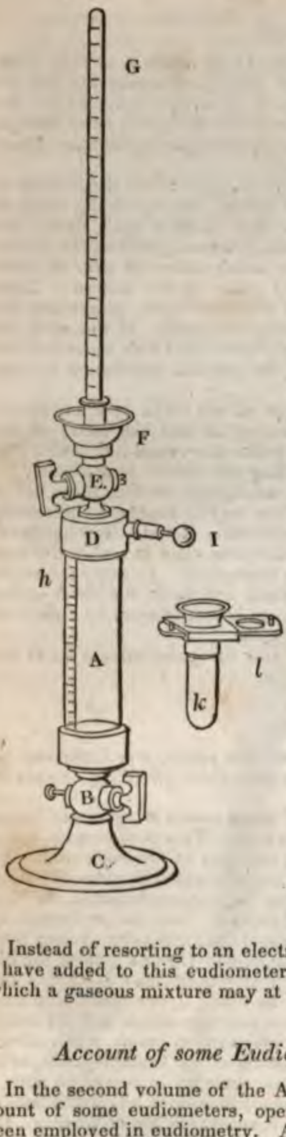
It is necessary that the water, the atmosphere, and the gases should be at the same temperature during the process.

199. *Volta's Eudiometer.*

The eudiometer, represented by this figure (see next page), was contrived by Volta, for the analysis of gaseous mixtures and compounds containing oxygen or hydrogen.

The body of this instrument, A, is a cylinder of glass, which is cemented below into a brass socket, united by a screw with the cock, B. This cock screws into a hollow brass pedestal, C, with the cavity in which the bore of the cock communicates. The glass cylinder is also cemented into a cap, D, which is surmounted by a cock, E, supporting the basin, F. The cavity of the basin communicates, through the bore of the cock when open, with that of the cylinder. Into the perforation in the bottom of the basin, the sealed tube, G, graduated into 200 parts, fastens by a screw cut upon a socket, into which the tube is cemented. On one side of the cylinder, there is a metallic scale, *h*, each division of which indicates a section of the bore of the cylinder equivalent to ten degrees on the tube. I, is an insulated wire for passing the electric spark through any explosive mixture which may be introduced into the cylinder. *k*, is a measure which holds as much gas as, when admitted into the cylinder, would be equal to ten divisions of the metallic scale, or to 100 degrees, if allowed to rise into the tube. This measure is furnished with a slide, in which a hole is represented at *l*. The measure is open when this hole is within it; it is closed when the hole is outside, as it appears in the engraving. By this mechanism it is rendered certain that, with care, the volume of air, taken at one time, will be equal to that taken at another.

In order to put this eudiometer into operation, open both the cocks, and depress it in the water of the cistern, until the water rises into the cylinder just above the lower cock. This cock is then to be closed, and the pedestal placed on the shelf of the cistern. Water is to be poured into the basin, until both the basin and cylinder are full. The glass tube, G, is then to be filled with water and inverted; and the orifice, meanwhile closed with the finger, is to be depressed below the surface of the water in the basin, without admitting air. The tube is then screwed into its place, so as to occupy the position in which it appears in the figure.



The upper cock being closed, let the measure, k, be plunged in the water of the cistern, the orifice open for the air to escape. Then invert it, the orifice being kept under the surface of the water. Next fill it with the mixture to be analyzed, as for instance a mixture of equal volumes of hydrogen and atmospheric air. Shut the orifice by moving the slide, allow any excess of air to escape, and then, placing the orifice of the measure under the pedestal of the eudiometer, open the orifice: the gaseous mixture will mount into the cavity of the cylinder. Shut the lower cock, and pass an electric spark through the included mixture. An explosion will ensue, and consequently a portion of the mixture will be condensed into water. By opening the cock, B, the deficit, thus produced, will be compensated by the entrance of an equivalent bulk of water. Open the upper cock, and allow the residual gas to mount into the graduated tube. Detach this tube from the eudiometer, and closing the orifice with the finger under water, before lifting it from the basin, sink it in water, until this liquid be as high without as within the tube. It may now be seen how far the residual air falls short of the 100 measures introduced.

It must be evident that we might operate on double the quantity of gas, by taking the measure full of it twice instead of once; and that a mixture of two volumes of air and one volume of hydrogen might be analyzed, by taking three measures equivalent to 300 parts. The loss by the explosion would be the number of degrees that the residue would fall short of 300, when in the graduated tube.

A mixture of three volumes of hydrogen with one of impure oxygen might be analyzed by taking the measure twice full, which is the same as 200 parts. In this case, one-third of the deficit would be the quantity of pure oxygen in $\frac{1}{4}$th of 200, or 50 parts, of the impure gas.

The metallic scale accompanying the cylinder I have never used. Since one of its divisions is equivalent to ten of those on the tube, observations made by means of the latter must be ten times more accurate.

Instead of resorting to an electric spark to produce the inflammation of the gases, I have added to this eudiometer a *galvano-ignition apparatus*, 111, by means of which a gaseous mixture may at any time be ignited with certainty.

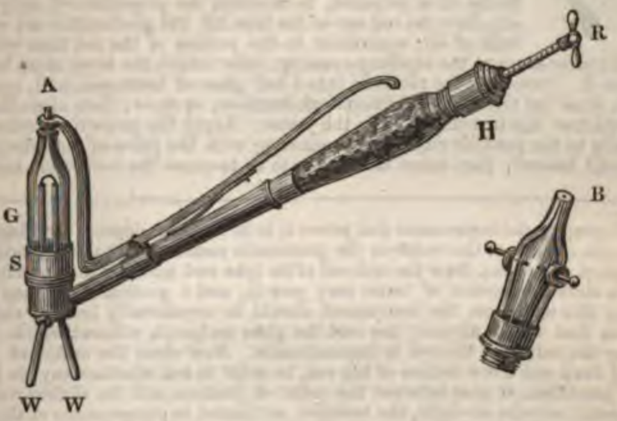
Account of some Eudiometers of an Improved Construction.

In the second volume of the American Journal of Science, I published an account of some eudiometers, operating by a mechanism which previously had not been employed in eudiometry. A graduated rod, sliding into a tube through a collar of leathers soaked in lard, and compressed by a screw so as to be perfectly airtight, was employed to vary the capacity of the tube, and at the same time to be a measure of the quantity of air, or of any other gas, consequently drawn in or expelled. About one-third of the tube was occupied by the sliding rod. The remainder, being recurved, and converging to a perforated apex, was of a form convenient for withdrawing measured portions of gas from vessels inverted over water or mercury.

There were two forms of the sliding rod eudiometer; one designed to be used with nitric oxide, or with liquids absorbing oxygen; the other, with explosive mixtures. The latter differed from the eudiometers for explosive mixtures previously invented, in the contrivance for exploding the gases, as well as in the mode of measuring them; a wire, ignited by galvanism, being substituted for the electric spark, as the means of inflammation.

I shall proceed to describe a eudiometer, for explosive mixtures, constructed on the principle of those above alluded to, with some improvements suggested by experience.

200. *Aqueous Sliding Rod Hydro-Oxygen Eudiometer.*



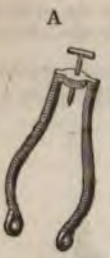
This cut represents a hydro-oxygen eudiometer, in which the measurements are made by a sliding rod, and the explosions are effected by the galvanic ignition of a platinum wire.

In the instrument represented by the preceding cut, the igniting wire is soldered into the summits of the two brass wires, W W, which pass through the bottom of the socket S, parallel to the axis of the glass recipient, G, within which they are seen. One of the wires is soldered to the socket. The other is fastened by means of a collar of leathers, packed by a screw, so that it has no metallic communication with the other wire, except through the filament of platinum, by which they are visibly connected above, and which I have already called the igniting wire. The glass has a capillary orifice at the apex, A, which is closed by means of a lever and spring (apparent in the drawing), excepting when the pressure of the spring is counteracted by the thumb of the operator. The sliding rod, R, is accurately graduated to about 100 degrees.

B, represents a glass with wires inserted through small tubulures, in the usual mode for passing the electric spark; should this method of producing ignition be deemed desirable, for the sake of varying the experiment, or for the purpose of illustration. This glass, the other being removed, may be fastened into the same place. The wires, W, W, remain, but should be of such a height as not to interfere with the passage of the electric spark. The instrument is operated with as usual, excepting the employment of an electrical machine, or electrophorus, to ignite the gaseous mixture. For the travelling chemist, the last mentioned mode of ignition may be preferable; because an electrophorus is more portable than a galvanic apparatus.

In damp weather, or in a laboratory where there is a pneumatic cistern, or amid the moisture arising from the respiration of a large class, it is often impossible to accomplish explosions by electricity.

I have found it expedient to secure the valve which closes the aperture in the apex of the instrument from the possibility of leakage during explosions, by means of an iron staple with a screw, represented in the cut on the next page. This fastens



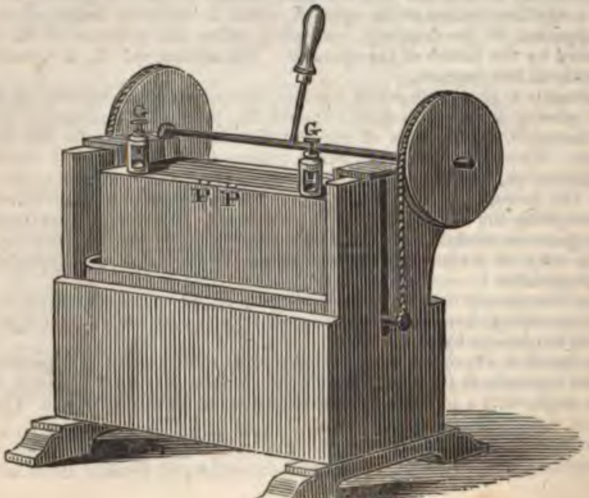
upon two pivots, one of which is inserted on each side of the brass socket, S, into which the glass recipient, G, is cemented. The staple hinges upon these pivots, and may be brought into a position in which the screw, A, being immediately over the valve, may be made to tighten it; or the staple may be made to hang down, so as not to be in the way, when the instrument is to be charged.

In order to use the eudiometer, it must be full of water, free from air-bubbles, and previously proved air-tight;* the rod being introduced to its hilt, and the capillary orifice open, in consequence of a due degree of pressure on the lever, by which it is usually closed. Being thus prepared, to ascertain the proportion of oxygen in the air, draw the rod out of the tube till 100 graduations are visible. A bulk of air, equivalent to the portion of the rod thus withdrawn, will of course enter at the capillary opening; after which the lever must be allowed to close it. Introduce the receiver into a bell glass of hydrogen, and, opening the orifice, draw out the rod 50 additional graduations, or more; then close the orifice, and withdraw the instrument from the water. Apply the projecting, wires, W W, severally to the metallic cups, communicating with the poles of the calorimotor represented below†; then move the handle so as to cause the receptacle holding the

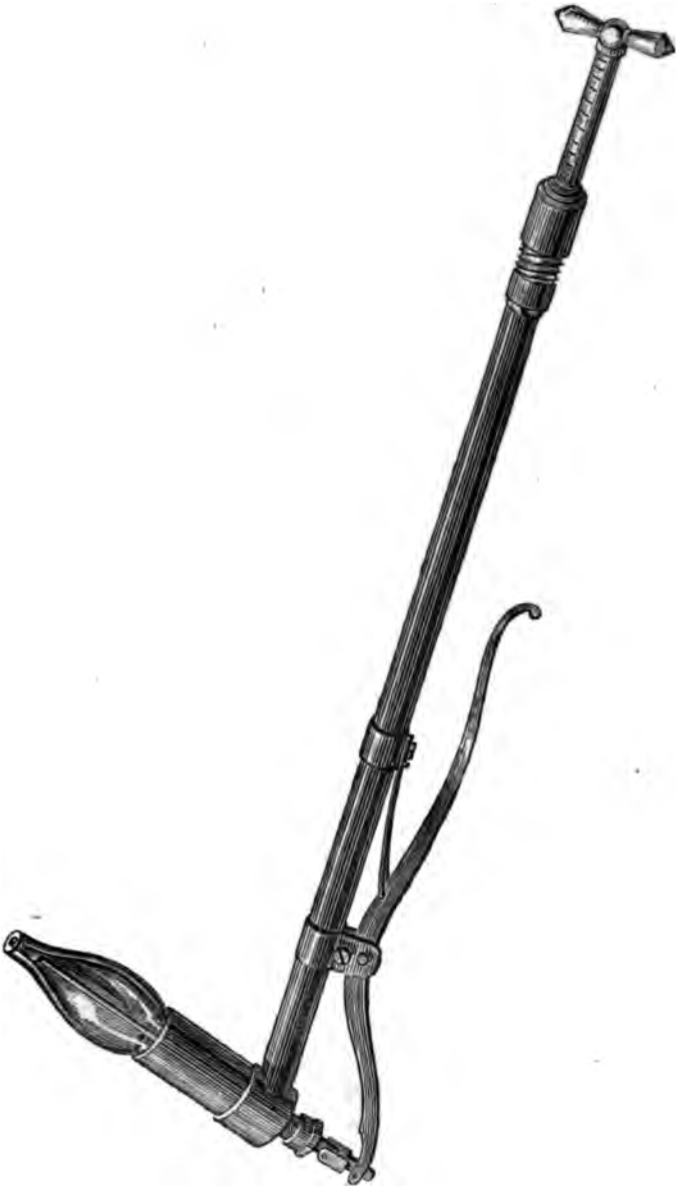
---

* To prepare the instrument and prove it to be in order, depress the glass receiver below the surface of the water in the pneumatic cistern, the capillary orifice being uppermost and open; draw the rod out of its tube and return it alternately, so that, at each stroke, a portion of water may pass in, and a portion of air may pass out. During this operation, the instrument should be occasionally held in such a posture, as that all the air may rise into the glass recipient, without which its expulsion by the action of the rod is impracticable. Now close the orifice at the apex, A, and draw out a few inches of the rod, in order to see whether any air can enter at the junctures, or pass between the collar of leathers and the sliding rod. If the instrument be quite air-tight, the bubbles, extricated in consequence of the vacuum produced by withdrawing the rod, will disappear when it is restored to its place.

† The following figure represents a calorimotor, containing two galvanic pairs, each consisting of two plates of zinc and three of copper, severally eight inches by nine. The arrangement may be understood from the description and engraving, pages 196, 197. It differs from that apparatus only in size, and in the number of the pairs. The mechanism is similar. Into two cavities or cups, in two masses of soft solder which constitute the poles of the instrument, the wires, W, W, of the eudiometer are forcibly pressed by one hand of the operator, while by the other the acid is made to act upon the plates through the instrumentality of the lever. Instantaneously on the ignition taking place, the circuit should be interrupted by lifting the eudiometer; as otherwise the wire might be fused.



Sliding Rod Gas Measure.



o rise about the plates. By the consequent ignition of the wire, the gas will de. The instrument being plunged again into the water of the pneumatic n, so that the capillary orifice, duly opened, may be just below the surface, ater will enter and fill up the vacuity caused by the condensation of the gases. esidual air being excluded by the rod, the portion of the rod remaining withe tube, will be in bulk equivalent to the deficit, which may consequently be ained by inspecting the graduation. I have performed this experiment in seconds.

xygen is to be examined by hydrogen, or hydrogen by oxygen, we must of e have a portion of each in vessels over the pneumatic cistern, and succes take the requisite quantities of them, and proceed as in the case of atmos c air.

other and perhaps more accurate mode of operating with this instrument is, eans of one of the volumeters above described, to make a mixture of the differases, in due proportion, in a bell glass. Thus, let two measures of atmosphe r be added to one of hydrogen; then on taking one hundred and fifty mea of the mixture into the eudiometer, there will be the same quantity of each s if 50 measures of hydrogen and 100 of air had been taken, as above described. der to ascertain the quantity of pure oxygen in the gas from nitre or manga one measure of it might be added to three of hydrogen. Then of 200 mea of the mixture, which might be taken into the eudiometer, 50 would conf the gas to be assayed, and 150 of hydrogen; and one-third of the deficit, d by the explosion, would be the quantity of pure oxygen in the 50 mea

hydrogen were to be assayed, as for instance the gas evolved by the reaction luted sulphuric acid with zinc, as in experiment 172, it would be proper to equal parts of the hydrogen and oxygen; as the gas which is not to be analyzed always be in excess. Taking then 200 measures into the eudiometer, twos of the deficit, caused by the explosion, would be the pure hydrogen in 100 ures of the gas under analysis. The required mixtures may be made with facility and accuracy, by either of the volumeters, described pages 220, 221.

201. *Sliding Rod Gas Measure.*

e construction of this instrument, represented by the opposite engraving, differs that of the sliding rod eudiometers, in having a valve which is opened and by a spring and lever, acting upon a rod passing through a collar of leathers. eans of this valve, any gas drawn into the receiver, is included so as to be from the possibility of loss, during its transfer from one vessel to another. instrument is much larger than the sliding rod eudiometers for explosive ures; being intended to make mixtures of gas, in those cases where one is to the other, in a proportion which cannot be conveniently obtained by taking or less volumes of the one than of the other, by means of the volumeters: for nce, suppose it were an object to analyze the air according to Dr. Thomson's of taking 42 per cent. of hydrogen. The only way of mixing the gases by a meter in such a ratio, would be to take the full of the volumeter 21 times of ogen, and 50 times of atmospheric air. By the large sliding rod gas measure object is effected at once, by taking 42 measures of the one, and 100 measures e other.

HEMICAL COMPOUNDS OF NITROGEN WITH OXYGEN.

These compounds are five in number, *nitrous* and *nitric* de, and *hyponitrous*, *nitrous*, and *nitric acid*. Their comsition is given in the following table:—

ol. or 1	½ vol. or 1 atom oxygen,	1 vol. nitrous oxide.
m of ni-	1 ,, or 2 atoms ,,	2 vols. nitric oxide.
gen =	1½ ,, or 3 ,, ,,	hyponitrous acid.
, forms,	2 ,, or 4 ,, ,,	1 vol. nitrous acid.
th	2½ ,, or 5 ,, ,,	nitric acid.

Of Protoxide of Nitrogen, or Nitrous Oxide.

This compound does not exist in nature. When artificially obtained it is gaseous; yet the experiments of Mr. Faraday have taught us that under great pressure, it may be converted into a liquid.

Preparation.—Nitrous oxide may be obtained by the action of dilute nitric acid upon zinc, or by exposing nitric oxide gas to iron filings, sulphites, or other substances attractive of oxygen. It is best procured by subjecting nitrate of ammonia to heat, and receiving the product in an apparatus described in the following article. As pure water absorbs this gas, Berzelius receives it over saturated solutions of common salt.

202. *Apparatus for evolving and collecting Nitrous Oxide.*

This apparatus is represented by the opposite engraving. A, is a copper vessel of about eighteen inches in height, and nine inches in diameter, which is represented as being divided longitudinally, in order to show the inside. The pipe, B, proceeds from it obliquely, as nearly from the bottom as possible.

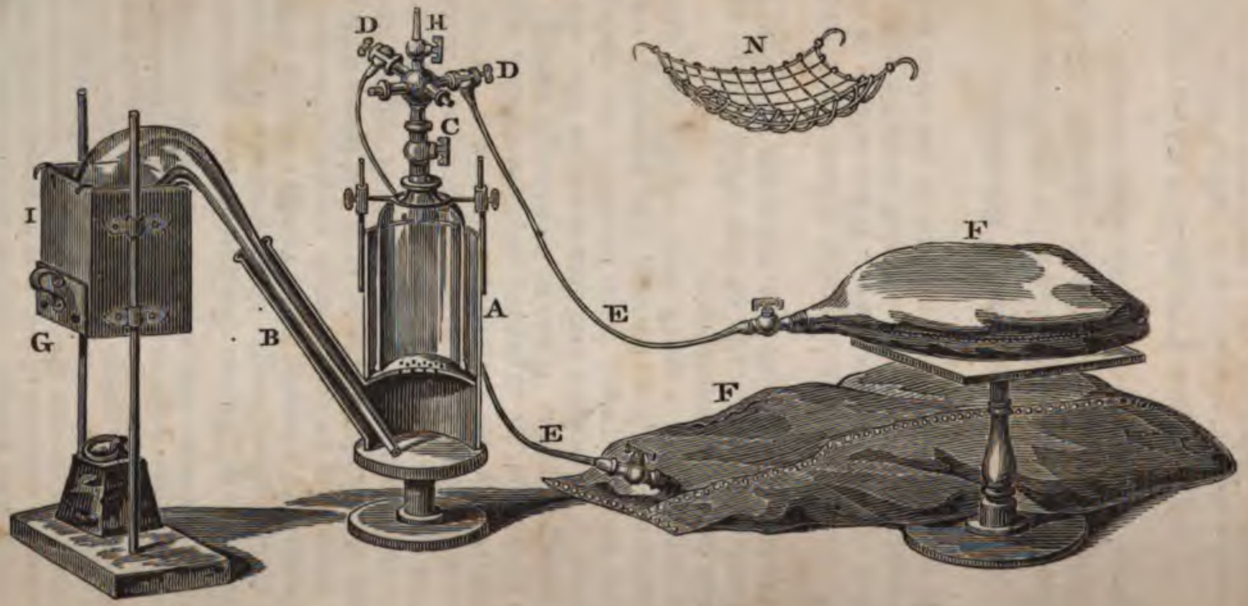
Above that part of the cylinder from which the pipe proceeds, there is a diaphragm of copper, perforated like a colander. A bell glass is surmounted by a brass cock, C, supporting a tube and hollow ball, from which proceed on opposite sides, two pipes, terminating in gallows screws, D D, for the attachment of perforated brass knobs, soldered to flexible leaden pipes, E E, communicating severally with leathern bags, F F. The larger bag is capable of holding about fifty gallons, the smaller one, about fifteen gallons.

The beak of the retort must be long enough to enter the cylinder, so that the gas, in passing from the mouth of the beak, may rise under and be caught by the diaphragm. This is so hollowed as to cause the gas to pass through the perforations already mentioned, which are all comprised within a circle less in diameter than the bell glass. The gas is, by these means, made to enter the bell glass, and is, previously to its entrance, sufficiently in contact with water, to be purified from the acid vapour which usually accompanies it. On account of this vapour, the employment of a small quantity of water, to wash the gas, is absolutely necessary; and for the same reason, it is requisite to have the beak of the retort so long, as to convey the gas into the water without touching the metal; otherwise the acid vapour would soon corrode the copper of the pipe, B, so as to enable the gas to escape. But while a small quantity of water is necessary, a large quantity is productive of waste, as it absorbs its own bulk of the gas. On this account I contrived the apparatus here described, in preference to using gasometers or air holders, which require larger quantities of water.

The seams of the bags are closed by means of rivets, agreeably to the plan of Messrs. Sellers and Pennock for fire hose. The furnace, I, is so contrived, that the coals, being situated in a drawer, G, may be partially or wholly removed in an instant. Hence the operator is enabled, without difficulty, to regulate the duration and degree of the heat. This control over the fire is especially desirable in decomposing the nitrate of ammonia, as the action otherwise might suddenly become so violent as to burst the retort. The iron netting, represented at N, is suspended within the furnace, so as to support the glass retort, for which purpose it is peculiarly adapted. The first portions of gas which pass over, consisting of the air previously in the retort, are allowed to escape through the cock, H. As soon as the nitrous oxide is evolved, it may be detected by allowing a jet from this cock to act upon the flame of a taper.

To obtain good nitrous oxide gas, it is not necessary that the nitrate of ammonia should be crystallized; nor does the presence of a minute quantity of muriatic acid interfere with the result. I have employed advantageously, in the production of this gas, the concrete mass formed by saturating strong nitric acid with carbonate of ammonia.

Apparatus for evolving and collecting Nitrous Oxide.



The saturation may be effected in a retort, and the decomposition accomplished exposing the compound thus formed to heat, without further preparation.

Rationale of the Process.—Nitrate of ammonia consists of nitric acid d ammonia; nitric acid, of five atoms of oxygen and one of nitrogen; d ammonia, of one atom of nitrogen and three atoms of hydrogen. In e atom of this salt, five atoms of oxygen, three of hydrogen, and two of trogen are, therefore, present. It must be evident that if, in consequence the heat, each atom of hydrogen takes one of oxygen, there will be but e atom of oxygen left for each atom of nitrogen. Hence, the whole of e salt is resolved into water, and protoxide of nitrogen or nitrous oxide.

Properties of Nitrous Oxide.—It is a permanent gas. 00 cubic inches weigh 47.25 grains. It supports the ombustion of a candle flame vividly; though nitric oxide as, containing twice as much oxygen, does not. Phoshorus is difficult to inflame in it, but burns with rapidity hen once on fire. The habitudes of sulphur are in this spect analogous to those of phosphorus. An iron wire rns in it nearly as well as in oxygen gas. Most of the mbustible bodies burn in nitrous oxide. When ignited ith hydrogen, an explosive reaction ensues, and water d nitrogen result. It has no attribute of acidity. When spired it stimulates and then destroys life. Its effects the human system, when breathed, are analogous to transient, peculiar, various, and generally very vivaous ebriety. It is much more rapidly and extensively luble in water than oxygen.

Homberg's pyrophorus, or that which I have contrived obtain from Prussian blue, takes fire on falling through e gas.

Mr. Faraday has shown that nitrous oxide may be liefied under great pressure. When nitrate of ammonia as heated at one end of a sealed recurved tube, nitrous ide was condensed into a liquid at the other end.

203. *Experimental Illustrations.*

The process and apparatus for producing, collecting, d breathing nitrous oxide gas, exhibited. The effect on ighted candle and on an iron wire, shown.

204. *Combustion of Phosphorus in Nitrous Oxide.*

There is a singular indisposition in the oxides of nitrogen to part with r oxygen to phosphorus, until it be intensely ignited either by an indescent iron, or by the access of uncombined oxygen.

This characteristic in the case of nitrous oxide, may be illustrated by means of an apparatus, like that employed for the combustion of phosphorus in oxygen, and of which the opposite engraving is a representation. It consists of a tall cylindrical receiver, and a tube descending through the neck and along the axis of the receiver, terminating in a capillary orifice over the cup for holding the phosphorus. The upper end of the tube, outside the receiver, is furnished with a cock, to which a gum-elastic bag inflated with oxygen is attached.

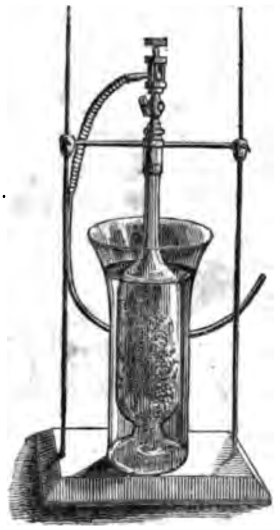
Under these circumstances, the receiver having been exhausted and filled with nitrous oxide, phosphorus, previously placed within the cup, may be melted without taking fire. But as soon as the cock communicating with the bag of oxygen is opened, an intense combustion ensues; since the oxygen, emitted in a jet from the capillary orifice of the tube, reaches the melted phosphorus, and excites it into active combustion, which the nitrous oxide afterwards sustains with great energy.

Of Nitric Oxide, formerly called Nitrous Air.

This oxide is an artificial product, and is obtained only in the gaseous state. Its tendency to combine with oxygen renders it impossible for it to exist where the atmosphere has access.

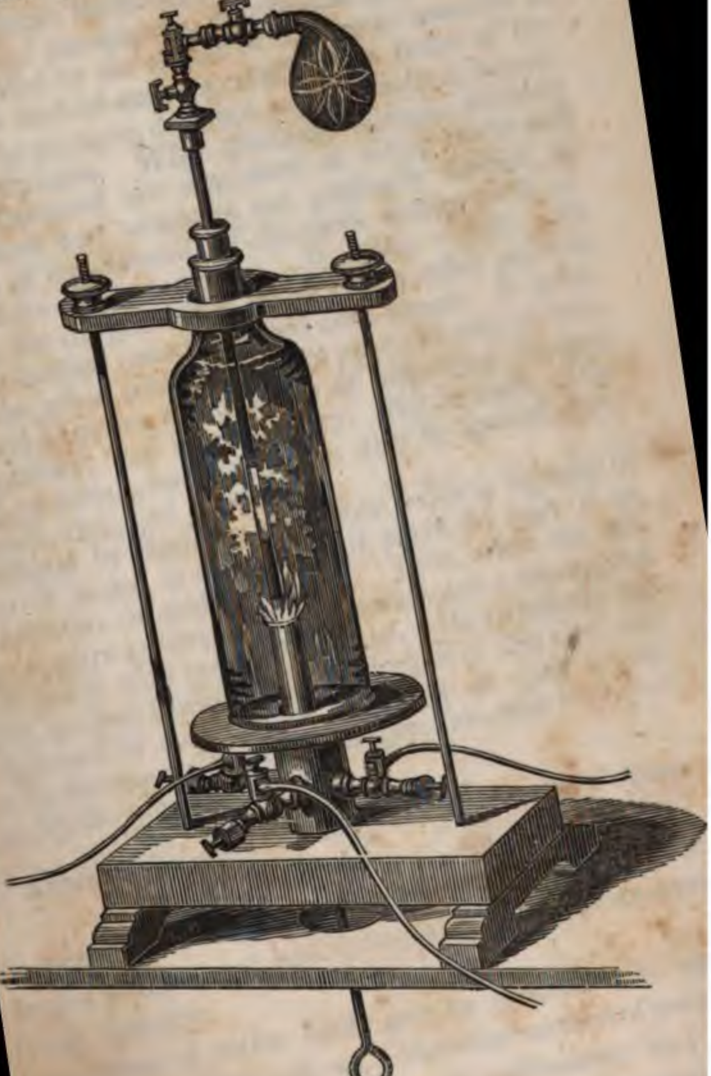
Preparation.—Nitrous oxide is evolved during the reaction between nitric acid, and copper, silver, and other metals.

205. *Self-regulating Apparatus for generating Nitric Oxide.*



The command of a sufficient supply of nitric oxide is most conveniently attained by means of a self-regulating apparatus, made in the manner which I am about to describe, and which is illustrated by the adjoining figure. A glass vessel, resembling a claret bottle elevated on a perforated foot, is placed within a glass jar, of which the rim rises to about the middle of the neck, which is furnished with a cock and gallows screw for the attachment of a flexible leaden tube. The cavity of the bottle being supplied with copper shreds or turnings, and the jar with diluted nitric acid,—by the reaction of the metal with the acid, gas is copiously evolved, producing red fumes by generating nitrous acid with the oxygen of the air. The emission of the gas should be permitted until the red fumes disappear. The cock may then be closed, unless it be desirable to allow the gas to be transferred to another vessel.

It should be understood that the acid passes into and out of the bottle, through the perforation in the stem; while by means of a fragment of he metallic shreds are prevented from escaping.



Combustion of Phosphorus in Nitrous Oxide.

Properties.—Nitric oxide is colourless, permanently elastic, and rather heavier than air. By water it is but slightly absorbed. It is not acid. It extinguishes a candle flame, but ignites Homberg's pyrophorus, and supports the combustion of phosphorus, if inflamed before immersion in it, or aided by the access of a minute quantity of oxygen. It is fatal to animals, renders the flame of hydrogen green by mixture, does not explode with it, but explodes with ammonia. When platinum sponge, recently ignited, is introduced into a mixture of nitric oxide and hydrogen, water and ammonia are gradually formed, in consequence of the elements of the oxide uniting with separate portions of the hydrogen. It unites rapidly with oxygen gas, the oxygen of the air, or of any other gaseous mixture, producing remarkable red acid fumes. It is absorbed by the green sulphate and the protochloride of iron. The solution acquires the property of absorbing oxygen, and is, therefore, used in eudiometry. Nitric oxide is decomposed by moistened iron filings; also by ignited charcoal, arsenic, zinc, and potassium.

It is alleged by Berzelius that nitric oxide is capable of uniting with bases, in which case it plays the part of an electro-negative or acid compound. Thus, when the calcination of nitre is carried to a certain point, a compound of nitric oxide with potash is formed. He overlooks the fact, first noticed I believe by Dr. Bridges of this city, and first explained by me, that the potassium in nitre is converted, by intense ignition, into the peroxide, which evolves oxygen by the affusion of water.

206. *Experimental Illustrations of the Properties of Nitric Oxide.*

Copper or silver being subjected to nitric acid, nitric oxide gas is extricated, and collected in bell glasses over water or mercury.

Absorption of nitric oxide gas by protochloride and green sulphate of iron, shown. Also the method of ascertaining its purity by the sliding rod eudiometer, and its application to eudiometry, in various ways, by means of that and other eudiometrical instruments.

Self-regulating reservoir of nitric oxide gas for eudiometrical experiments. Absorption of oxygen gas by nitric oxide, and the consequent acidity, made evident by the effect on litmus. Homberg's pyrophorus in falling through the gas is ignited.

Of Hyponitrous Acid.

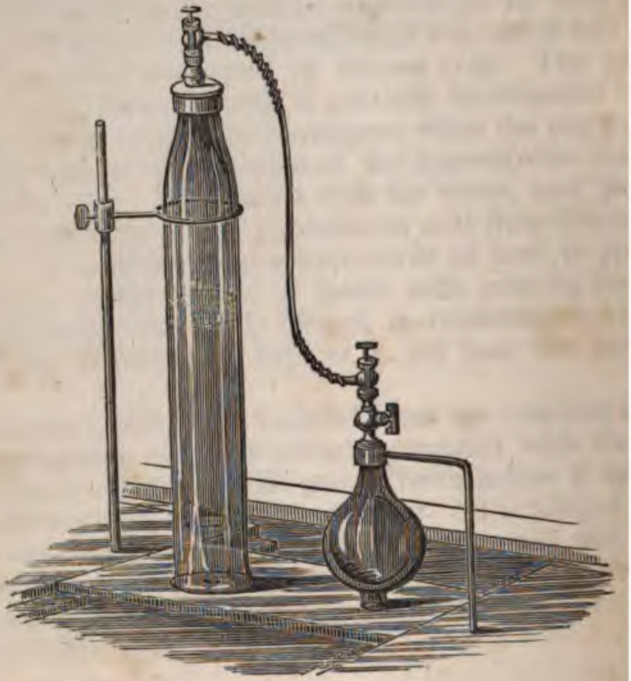
This acid was isolated in the following manner by Dulong. Having subjected a mixture of four volumes of nitric oxide with one of oxygen, in a tube, to a freezing mixture, he obtained the acid in question in the form of a deep green liquid, so volatile as to be converted into a red vapour, unless restrained by intense cold. The hyponitrous acid, thus procured, is partially decomposed by water into nitric oxide which escapes; while the oxygen, combining with another portion of the hyponitrous acid, forms nitric acid. This unites with the water, and protects the remainder of the hyponitrous acid from decomposition. It is alleged that a hyponitrite of lead is produced, when nitrate of lead is boiled with metallic lead. According to Berzelius, it is formed, in combination with bases, when nitrates are kept at a red heat for some time.

Hyponitrous acid, when isolated, does not combine directly with bases, but is resolved by contact with them into a nitrate and nitric oxide gas. Nevertheless it may be transferred from one base to another. It is alleged to form a crystalline compound with sulphuric acid, and to combine with nitric acid; but it is questionable whether, in combining with nitric acid, it is not resolved into nitric oxide and nitric acid.

Of Nitrous Acid.

This combination may be procured in the gaseous state, by mixing two volumes of deutoxide of nitrogen, and one of oxygen; or by subjecting fuming nitric acid to heat, and collecting the product in a receiver. It is also procured by distilling nitrate of lead. Moist nitrous acid is a gas of a deep red colour. When anhydrous it is a liquid of an orange-yellow which boils at 72°. In this form it may be obtained by passing deutoxide of nitrogen and oxygen, *both previously dried*, through a tube

Synthesis of Nitrous Acid.



with fragments of porcelain; or by desiccating the
of lead before employing it as above mentioned.
zelius affirms that there is no compound of nitrogen
ch the name of hyponitrous acid should be given.
cid, heretofore thus named, he calls nitrous acid;
considers the combination above described, gene-
alled nitrous acid, as a double acid, composed of
rous acid and nitric acid, or of nitric acid and ni-
ide. As this compound cannot, as he alleges, com-
ith bases without decomposition, he objects to con-
g it as a distinct acid.

Synthesis of Nitrous Acid by the Union of Nitric Oxide with Oxygen Gas.

eans of a brass cap with a cock and gallows screw, let a tall cy-
glass receiver, represented in the opposite engraving, be made to
icate with a pear-shaped glass vessel. Previously, however, to
nmunication being made, let both vessels be filled with water, by
ng them under the surface of that liquid in the well of the pneu-
istern, the cocks being first opened to allow the escape of air, and
rds closed. The apparatus is then to be placed on the shelf of the
as represented.

allow the pear-shaped vessel, which I will call a volumeter, to be
lled with nitric oxide, and as often allowed to yield up its contents
eceiver. Then fill the volumeter with oxygen gas. In the next
pen the communication again with the receiver. The oxygen,
into the nitric oxide, produces dense fumes of nitrous acid. At
consequence of the rise of temperature which attends the combina-
ere appears some expansion; but a speedy absorption of the nitrous
erated, causes the water to rise, and nearly fill the receiver. From
use, I have never been able to attain a complete condensation by
cess.

Application of Nitric Oxide Gas to Eudiometry.

roperty which this substance has of forming with oxygen, nitrous or hypo-
cid, either of which is absorbed by water, has caused it to be used in eu-
cal operations; but owing to the variable proportions in which the above
ed compounds are liable to be formed, the results obtained have been
uncertain, and the directions for using nitrous oxide, given by such emi-
emists as Dalton, Gay-Lussac, and Thomson, are at variance. Gay-Lussac
empirical formula, agreeably to which one-fourth of the condensation, pro-
y a mixture of equal parts of atmospheric air and nitric oxide, is to be as-
s the atmospheric oxygen present.

two volumes of nitric oxide, a volume of nitrogen is combined with one
of oxygen, occupying the same bulk as if merely mingled,—to convert the
ide into nitrous acid, which consists of the same quantity of nitrogen with
mes of oxygen, one volume of oxygen must be added. Of course, if ni-
id be the product, one-third of the deficit produced, would be the quantity
pheric oxygen present. This would be too much to correspond with the
of Gay-Lussac.

sing hyponitrous acid produced, only half as much oxygen would be re-
s is necessary to produce nitrous acid; so that instead of the tw
oxide taking one volume, they would take only half a volume.
2½, is the same as 1 in 5, or one-fifth, which is too little for G

The formula recommended by Dr. Thomson, agreeably to which one-third of the deficit is to be ascribed to oxygen, is perfectly consistent with the theory of volumes, and much more consonant with the results of my experiments than that recommended by the celebrated author of that admirable theory.

The late Professor Dana ingeniously reconciled Gay-Lussac's statement with the theory of volumes, by suggesting that half a volume of oxygen may take one volume of the nitric oxide, and another half volume of oxygen, two volumes.

vol.		vol.	
½	oxygen takes	1	oxide and forms nitrous acid.
½	oxygen	2	oxide and forms hyponitrous acid.
–		–	
1.		3	

The total condensation here would be four volumes, and the deficit due to oxygen is one volume, or one-fourth.

With the deference due to a chemist so distinguished as the author of the formula in question, I long strove unsuccessfully to verify his statements. Agreeably to a great number of experiments, annually repeated during many years with different instruments, it has been found that, when three volumes of nitric oxide are mixed, over water, with five of atmospheric air, nearly the same condensation is effected, as when like quantities of air and hydrogen are ignited together. In order to demonstrate the truth of this allegation to my numerous class of pupils, I have employed the apparatus represented by the opposite engraving, and described in the following article. In this the volumes employed are so large as to make the results strikingly evident to the most remote observer.

208. *Volumescope for the Analysis of Atmospheric Air by Nitric Oxide.*

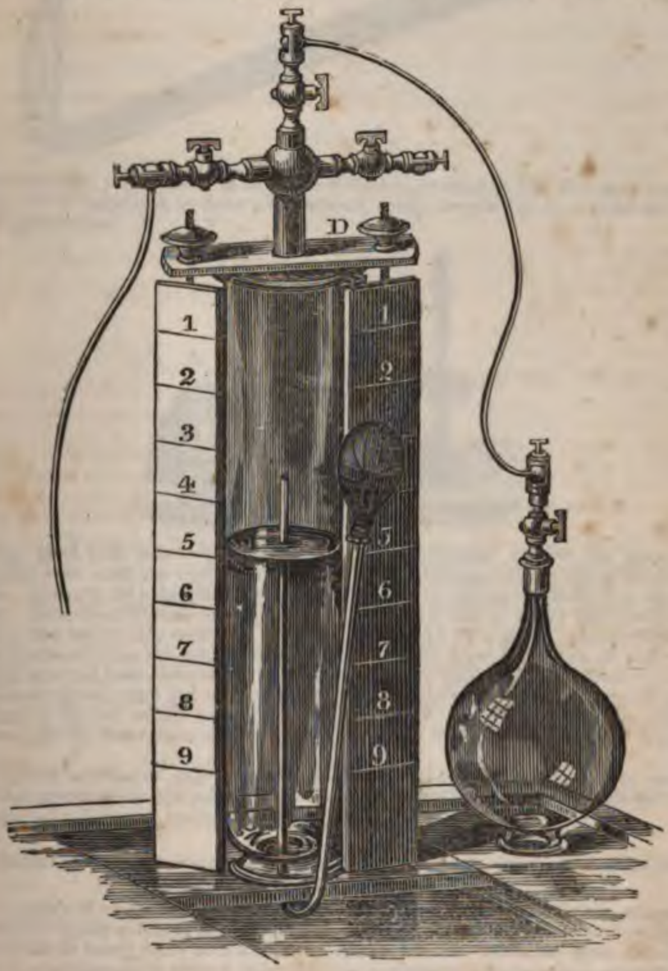
Secured in a screw rod and plate frame, there is a glass cylinder thirty inches in height, and about five inches in diameter. Into the brass plate which closes it at top, three cocks are inserted, each provided with a gallows screw. By means of a flexible leaden pipe, let one of the cocks be made to communicate with an air pump. Let the other cock, by like means, be made to communicate with a pear-shaped glass vessel, which acts as a volumeter, or volume measurer. Let the cylinder, by means of a scale placed on one side of it, be graduated so as to hold eight volumes, any three of which shall be equivalent, collectively, to the contents of the volumeter. The apparatus being thus prepared, and secured over one of the wells of the pneumatic cistern, (151,) exhaust the cylinder by means of the air pump, so as to cause the water to rise in it, until by the scale only five volumes of atmospheric air are left, and then open a communication with the volumeter. The air contained in this vessel will then pass into the cylinder, and, if the graduation be consistent with the premises, the water will sink to the graduation designating the eighth volume. Now let the water, by means of the air pump, again be raised to the graduation marking the fifth volume, and introduce into the volumeter as much nitric oxide as it will hold. If, under these circumstances, the communication between the pear-shaped vessel and the cylinder be re-established, the nitric oxide will pass into the cylinder, and, combining with the oxygen of the contained air, will produce nitrous acid in red fumes, which the water will begin sensibly to absorb. This absorption is promoted and completed by jets of water, projected vertically through the mingled gases, by means of the recurved pipe, and gum elastic bag to which it is attached. It has been shown by the preceding part of the process, that the contents of the volumeter, added to five of air, would make eight volumes, were there no absorption; but the actual residue, when the experiment is well performed, is always a little less than five volumes, indicating that a little more than one volume of oxygen is contained in the five volumes of air employed, and that this is condensed by combining with twice its bulk of nitric oxide. The nitrous acid, usually thus called, consists of one volume of nitrogen and two volumes of oxygen. Of course, to convert into this acid, nitric oxide, consisting of one volume of nitrogen and one volume of oxygen uncondensed, one volume of oxygen must be added.

209. *Sliding Rod Eudiometer for Nitric Oxide.*

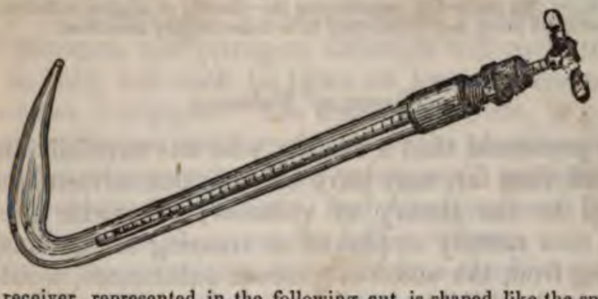
This figure (see next page) represents the form of the sliding rod eudiometer, which I have found most serviceable for experiments with nitric oxide gas, or those in which green sulphate or the protochloride of iron, saturated with nitric oxide, is employed.

The rod for these experiments is graduated into 150 large divisions, severally di- ed into five small ones, which being each considered equal to two degrees, the le number of degrees may be assumed either as 150 or as 1500.

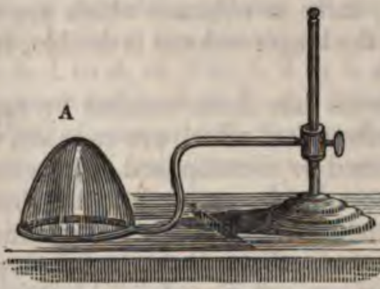
Volumescope for the Analysis of Atmospheric Air by Nitric Oxide.



The mode in which the rod is made to measure gaseous fluids has been explained in article 200.



The receiver, represented in the following cut, is shaped like the small end of an egg, and is employed in these experiments, being mounted so as to slide up and down upon a wire.



Being filled with water, and immersed in the pneumatic cistern, the apex, A, being just even with the surface of the water,—by drawing out the rod of the eudiometer, take into the tube 100 measures of atmospheric air, and transfer it to the receiver. Next take 50 measures of nitric oxide from a bell as above described, and add it to the air in the receiver. Wash the mixture by a jet of water, which is easily produced from the apex of the instrument, and draw the whole of the residual gas into the tube, continuing to draw out the rod until 150 graduations appear. In the next place, eject the residual gas from the instrument: the number of graduations of the rod which remain on the outside of the tube, shows the deficit produced by the absorption of the oxygen and nitric oxide, in the state of nitrous acid.

In a great number of experiments, I have found the deficit to agree very nearly with that produced by the explosion of the same quantity of air with hydrogen, in the aqueous sliding rod hydro-oxygen eudiometer.

210. *Method of ascertaining the Purity of Nitric Oxide by means of a Solution of Protochloride, or Green Sulphate of Iron.*

The purity of nitric oxide is easily ascertained by means of a solution of protochloride, or green sulphate of iron, and the sliding rod eudiometer above described. A small bottle being filled with a solution of the salt, and inverted upon the shelf of the hydro-pneumatic cistern, take into the eudiometer one hundred measures of the gas, and transfer them to the bottle, which must be agitated for two or three minutes. The receiver, represented in the above cut, being filled with water, and depressed into the water of the hydro-pneumatic cistern, till the apex, A, is on a level with the surface, throw up into it the residual gas. In the next place, draw it into the eudiometer. The distance which the rod is drawn out, shows the quantity of gas unabsorbed by the solution, and of course the impurity in the nitric oxide.

A saturated solution of nitric oxide in the above mentioned ferruginous solutions, has the power of absorbing oxygen, and was re[illegible] by Sir H. Davy as the means of ascertaining the quantity of that gas [illegible] ng them would be the same as that just described, taking oxygen into the eudiometer instead of nitric oxide, and filling the bottle with the ferruginous solution of nitric oxide, instead of the solution of the pure sulphate or protochloride of iron.

I have found this method of ascertaining the quantity of oxygen in the air, much more tedious and much less satisfactory than those already described.

Theory of Volumes.

It is presumed that a reader, who has carefully studied this work thus far, may have his attention advantageously directed to the theory of volumes; otherwise the language, now usually employed in treating of combinations resulting from the union of gaseous substances, would not always be intelligible to him.

It has been advanced by Gay-Lussac that substances, when aëriform, unite in volumes which are equal, or that when unequal, the larger volume is double, triple, or quadruple the other.

This hypothesis has been verified by experiment with respect to all substances which are capable, while gaseous, of being combined or decomposed. It is extended by inference to other substances, under the idea that all are susceptible of the aëriform state. A volume is said to be the equivalent of another volume, when capable of forming with it a definite compound, or when just adequate to displace it from combination.

It must be evident, a priori, that if each atom, of whatever kind, were to occupy in the aëriform state an equal space, atoms might be as well represented by equal volumes as by their equivalent numbers; the former affording by measure, what the latter give by weight. Now experience justifies the belief that, in general, atoms do assume an equality of volume when rendered aëriform, and that, when the bulks assumed are unequal, the inequality may be removed by multiplying or dividing, by a whole number, those volumes which are smaller or larger than the rest. This is all that the hypothesis of Gay-Lussac requires.

Berzelius infers that water, and the protoxides of chlorine and nitrogen, each consist of one atom of oxygen, and two atoms of the other ingredient. Admitting this to be a correct inference, equivalent weights of the four elementary gaseous substances above mentioned, actually occupy equal spaces; so that their atoms are as well represented by equal volumes, as by the numbers indicating ieir ratio to each other in weight. But if we suppose iat, in the compounds above mentioned, there is only one tom of each ingredient, the equivalent volumes of chloine, hydrogen, and nitrogen, although still equal to each ther in bulk, will each be twice as large as the equivaent volume of oxygen. The British chemists, in general referring the last mentioned view of the atomic constituion of the compounds above mentioned, represent the toms of chlorine, hydrogen, and nitrogen, each by one olume, the atom of oxygen by half a volume.

When gaseous substances enter into combination preerving the aëriform state, in some cases there is a reducion of volume, in others none. When a reduction does nsue, the bulk, or resulting volume of the compound, is o the aggregate bulk of the constituent volumes, either s 1 to 2, 1 to 3, 1 to 4, or 2 to 3, 2 to 5, &c.

This will be rendered evident by the following table, in hich the number of atoms and the number of volumes hich enter into some important compounds, are repreented by corresponding squares. Each square stands for volume, and half a square for half a volume. The first olumn contains the name of each gas or vapour; the econd, the equivalent volume of the gas if simple, or an ssociation of the volumes representing its constituents f compound; the third, the resulting volume of the comound formed; and the last, the pressure, expressed in tmospheres, necessary to produce liquefaction.

Among the instances cited in the table, it will be seen hat there is none in which the bulk of the constituent olumes is to that of the resulting volume in a ratio reater than that of 3 to 1. The only permanent gas, in hich the elements are alleged to exist in a state of reater condensation, is olefiant gas, consisting of two olumes of the vapour of carbon, and two volumes of hyrogen, condensed into one volume. There are some apours, consisting of the same elements in the same tomic proportion, in which 8 or 9, or, according to Dr. homson, even 25 constituent volumes are contained in resulting volume.

Table of the Equivalent Weights and Volumes of some Gases and Vapours.

Gases and Vapours.	Component Volumes.	Resulting Volumes of Compounds.	Pressı Liquefi Atmos
Oxygen	O 8		
Chlorine	Cl 36		4 at
Protoxide of chlorine	Cl 36 O 8	44	
Hydrogen . . .	H 1		
Steam	H I O 8	9	
Chlorohydric acid	C 36 H 1	37	40 at
Nitrogen	N 14		
Atmospheric air .	N 14 N 14 O 8	36	
Nitrous oxide . .	N 14 O 8	22	50 at
Nitric oxide . .	N 14 O 8 O 8	30	
Nitrous acid . .	O 8 O 8 O 8 O 8 N 14	46	
Ammonia . . .	H 1 H 1 N 14 H 1	17	6½ at

Of Nitric Acid.

Although, under ordinary circumstances, nitrogen will not combine with oxygen; yet, when mixed with it, and exposed to a succession of electric sparks, nitric acid, one of the most important agents in chemistry, is generated. Berzelius alleges that traces of nitric acid, in combination with ammonia, may almost always be discovered in the ain water accompanying thunder storms. This chemical combination is probably produced by lightning. The ame author states that when a jet, consisting of one vo-ume of nitrogen and fourteen of hydrogen, is inflamed while flowing into a vessel containing oxygen, nitric acid is produced. There are probably some unknown means, by which chemical union is induced between nitrogen and oxygen; whence the great quantity of nitrate of potash spontaneously produced in various situations.

It has been supposed that this acid is formed during the eudiometrical analysis of atmospheric air by hydrogen; and that the deficit being thus increased, leads to an undue estimate of the oxygen. I consider this impression erroneous; as upon one occasion, by exploding successive portions of hydrogen with atmospheric air, I collected nearly half an ounce of water, and found it devoid of acidity.

Preparation.—The production of nitric acid by electricity is too laborious to be resorted to for the purpose of the chemist.

Agreeably to the usual process, nitre, which consists of nitric acid and potash, is subjected to heat with an equal weight of sulphuric acid, in a glass, porcelain, or iron retort, communicating with a glass receiver. The nitric acid is displaced by the superior affinity of the sulphuric acid for the potash, and, being vaporized by the heat, passes into the receiver, where it condenses into a liquid. Thus obtained, it is more or less contaminated with nitrous acid or nitric oxide, and chlorohydric and sulphuric acids. By distilling from it about a third of the whole quantity, the nitrous and chlorohydric acids pass over into the receiver with the portion of nitric acid distilled, leaving the residue in the retort free from them. Sulphuric acid may be removed by distilling the nitric acid from one-eighth of its weight of pure nitre, or by the addition of baryta, which precipitates in the form of an insoluble compound with the sulphuric acid. Chlorohydric acid may in like manner be removed by a solution of silver; as this metal forms with the chlorine an insoluble compound which precipitates.

Properties.—Nitric acid emits pungent suffocating fumes, and has a peculiar odour. When pure it is colourless, but when exposed to the light, it is slowly decomposed into oxygen gas, and nitrous acid or nitric oxide which is absorbed, giving an orange colour to the nitric acid. This decomposition takes place much more rapidly in the sun. Nitric acid cannot be obtained free from water. With almost all the metals it reacts powerfully, also with organic substances, causing them to be oxidized. It stains and destroys the skin. It may be considered as consisting of the ingredients of atmospheric air in the liquid form, but containing ten times as much of the active principle, oxygen. It is the most energetic principle in gunpowder. In its highest state of concentration, at a specific gravity of 1.55, one atom of the acid contains one atom of water. This concentrated acid boils at 175° and freezes at — 40°. When it contains one atom of acid to four of water, it has a specific gravity of 1.42, and boils at 248°. Any acid, whether weaker or stronger than this, has the boiling point at a lower temperature. If weaker it is strengthened, if stronger it is weakened, by boiling; and acids of all degrees of strength become, by the continued application of a sufficient degree of heat, of the specific gravity of 1.42. The officinal specific gravity is 1.5, in which case it contains two atoms of water to one of acid.

Nitric acid is employed in giving a yellow colour, and for various other purposes in manufactures. It is used in medicine for fumigations, in cases in which chlorine is unsuitable.

211. *Experimental Illustrations.*

The extrication and distillation of nitric acid, shown by means of a glass retort and receiver, heated by a lamp or small sand bath. Its action on various substances exemplified.

Orange-coloured Fuming Nitric Acid, called Nitroso-nitric Acid in the Swedish Pharmacopœia.

'hatever proportion sulphuric acid may be employ-
he process just described for procuring nitric acid,
uid obtained is of an orange colour. This colour
es deeper, when the quantity of sulphuric acid em-
is insufficient to produce a bisulphate with the
. I am under the impression that, in some degree,
ne result follows when the acid exceeds the propor-
quisite to produce the bisulphate. In either case the
which in the absence of some other base is indis-
le to the existence of nitric acid, is not furnished in
nt quantity. Hence the acid is partially resolved
ygen and nitrous acid, which latter, together with the
cid, passes into the receiver, constituting an orange-
ed fuming liquid, mentioned by Berzelius under the
of *nitroso-nitric acid.* This acid, by exposure to
lisengages nitrous acid gas, and becomes colourless
acid. Nitroso-nitric acid ignites essential oils, car-
nd phosphorus; the latter explosively. It is much
energetic in its reaction with such substances than
itric acid, which, probably, when nitric oxide is not
t, requires for its existence a larger proportion of
I deem it probable that it is with nitric oxide, not
s or hyponitrous acid, that nitric acid is combined
roso-nitric acid. Berzelius conceives that either
f its composition may be correct.

212. *Experimental Illustrations.*

ction of nitroso-nitric acid with carbon and oil of
tine, exhibited.

the Agency of Nitric Oxide in generating Sulphuric Acid.

a nitric oxide, atmospheric air, sulphurous acid, and aqueous vapour
gled, a crystalline compound is formed, which, if the operation
rmed within a glass vessel, will appear upon the interior surface
ystalline deposition, resembling hoar frost. When water is added
compound, it is resolved into sulphuric acid and nitric oxide. The
combines with the water, while the latter escapes in the gaseous
roducing with oxygen, if present, the red fumes of nitrous, or hypo-
acid. It may be inferred that hyponitrous acid, produced as above
ed, yields one atom of oxygen to the sulphurous acid, converting
sulphuric acid. The acid, thus produced, unites with the nitric
nd water; but on being subjected to a larger portion of water, for
it has a greater affinity, the nitric oxide is allowed to esc

These habitudes of the agents in question excite greater interest, on account of their agency in the generation of sulphuric acid, one of the most valuable of the instruments which have been placed within the reach of the chemist.

213. *Experimental Illustration of the Reactions which occur in the Manufacture of Sulphuric Acid.*

Into a glass globe with three tubulures, introduce on one side the beak of a half pint retort, containing about a pound of mercury, and as much sulphuric acid as will cover it to the depth of half an inch, applying to the retort a chauffer of coals. Into the other tubulure, fasten the termination of a pipe proceeding from a self-regulating reservoir of nitric oxide gas. The third tubulure should be closed by a glass stopple. The mercury takes one atom of oxygen from the sulphuric acid, converting it into sulphurous acid which enters the globe. As soon as this appears to have taken place, a portion of the nitric oxide gas is allowed to enter from the opposite side. Meeting with atmospheric air within the vessel, the nitric oxide will produce red fumes, which, encountering the sulphurous acid, will condense into a crystalline deposition. Occasionally, the stopple must be lifted to allow the access of fresh air; and the supply of this and the gases must be so regulated, that the red fumes shall be repeatedly produced and condensed. When a deposition of crystalline matter, sufficiently striking, has been produced, if water be poured into the globe, the deposition will be speedily decomposed with an evolution of nitric oxide. This gas, meeting with the oxygen of the air, produces red fumes, which, by the readmission of sulphurous acid, are again condensed with it into crystals. These crystals, as before, by the addition of water, are decomposed into nitric oxide gas and sulphuric acid. The water in the globe, being decanted and tested, gives decided indications of the presence of sulphuric acid.

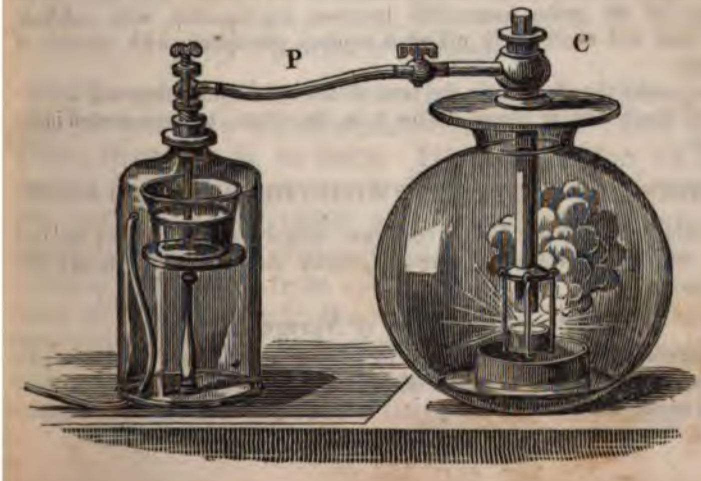
Of the Process usually employed in the Manufacture of Sulphuric Acid.

The means employed in the experiment just described, are convenient for the purpose of illustration, but could not be resorted to profitably for the manufacture of sulphuric acid. The combustion of one portion of sulphur, and the simultaneous deflagration with nitre of another portion, (the fumes created in both ways being received in a large chamber lined with lead, and covered at bottom with water) are the means usually employed by the manufacturing chemist. Each atom of nitre consists of an atom of potash and an atom of nitric acid. Three out of the five atoms of oxygen in each atom of the acid, unite with an atom of sulphur, converting it into sulphuric acid, which combines with the potash. The two remaining atoms of oxygen, together with the nitrogen of the acid, are evolved as nitric oxide, which, with atmospheric oxygen, moisture, and the sulphurous acid produced by the burning sulphur, generates the crystalline compound above described. Of late years, the presence of an adequate quantity of moisture has been insured by the introduction of steam at proper intervals. The crystalline compound, subsiding into the water, is decomposed into sulphuric acid which remains in solution, and nitric oxide. This oxide, meeting with further portions of oxygen and sulphurous acid, again contributes to the formation of the crystalline compound, to be again decomposed. This process continues, until the water in the chamber becomes sufficiently impregnated with sulphuric acid, when it is transferred to leaden boilers. In these it is concentrated by boiling, until it begins to act on the lead. It is then removed to a platinum alembic, or glass retorts, and boiled down to the specific gravity of 1.85. After it has reached that density, no farther concentration can be effected by heat. This, accordingly, is the standard specific gravity of the sulphuric acid of commerce.

In some manufactories, nitric oxide is supplied by the reaction of nitric acid with starch, sugar, or molasses; oxalic acid being produced at the same time, the sale of which reduces the cost of the process.

214. *Production of Sulphuric Acid further illustrated.*

The apparatus here described, serves to show, in miniature, the process for generating sulphuric acid.



Into a globular glass vessel holding about eight gallons, represented in the preceding figure, introduce as much water as will cover the bottom to the depth of about two inches. The vessel has a wide mouth, which is ground to fit a circular metallic plate. Through a hole in the centre of this plate, a gun barrel, open at both extremities, is made to descend. From the lower extremity, a ring of about two inches in diameter is suspended by wires, hooked to a perforated circular piece of sheet metal, which encircles and is soldered to the barrel. In the ring thus suspended, a conical frustum of iron, having an hemispherical cavity, is seated, so as to be a little above the water. Between the outside of the gun barrel, and the inside of the brass casting, C, which supports it, there is a passage from the pipe, P, into the cavity of the globe. This pipe communicates also with the water of a tumbler, supported within the bell glass. A tube leads from a suction pump into this vessel, which is placed on the shelf of the pneumatic cistern, covered with water as usual.

The apparatus being thus arranged, the metallic plate, with the gun barrel, ring, and frustum appended to it, must be removed from the globe, the iron frustum lifted out of the ring, and some nitrate of potash (nitre) being introduced into the cavity in the frustum, it must be made moderately red-hot. It is then to be restored to its seat in the ring, below the gun barrel, and the plate and gun barrel must be returned to their previous position over the mouth of the globe, so that the whole may be situated as represented in the engraving. Lumps of brimstone, about the size of peas, are to be dropped through the gun barrel into the melted nitre. As each lump reaches the nitre a combustion ensues, equally remarkable for beauty and brilliancy. The globe then becomes filled with sulphurous acid gas, accompanied by nitric oxide gas, and a crystalline deposition ensues. Meanwhile, to keep up a supply of oxygen within the globe, and to prevent the escape of fumes into the apartment, the suction pump is put into operation, in order to draw the fumes out of the globe, and cause them to be replaced by air, which enters through the gun barrel. The water rises from the cistern into the bell, until the resistance which it offers to further elevation, is greater than that which the water, in the tumbler on the stand, opposes to the entrance of air from the pipe; and, consequently, the air is drawn from the globe through the water in the tumbler, by which the fumes arising from the combustion are arrested, especially if liquid ammonia shall have been previously added to the water. The water at the bottom of the globe meanwhile becomes impregnated with sulphuric acid, and will accordingly afford a copious precipitate with chloride of barium.

To protect the globe from the heat of the red-hot iron frustum, a cylinder of sheet lead is placed below it in the water, as represented in the figure.

COMPOUNDS OF NITROGEN WITH CHLORINE AND IODINE.

Neither chlorine nor iodine combines directly with nitrogen; but both unite with the nitrogen of ammonia, under circumstances which I shall mention presently.

Of Chloride of Nitrogen.

This compound may be obtained by placing a bell glass, filled with chlorine, over a solution of one part of nitrate of ammonia in twelve of water, at th[illegible]ture of 70°.

The chloride appears in drops, which resemble olive oil, and which, being heavier than water, subside to the bottom of the basin containing the solution. It is remarkable that this substance does not explode with many combustibles, which would appear more likely to decompose it than those with which it does explode. Thus it explodes with turpentine or caoutchouc, but not with camphor.

The force with which a minute portion of chloride of nitrogen explodes, on contact with oil of turpentine, would hardly be credited by those who have not witnessed this phenomenon. An open saucer of Canton china was fractured by a globule not larger than a grain of mustard seed. The glass tube employed to project the globule into the saucer, was violently dispersed in fragments.

Of Iodide of Nitrogen.

When iodine is kept in liquid ammonia, it is converted into a brownish-black substance, which is iodide of nitrogen, and which may be collected and dried on bibulous paper at a gentle heat. The iodide of nitrogen thus formed, evaporates spontaneously. It explodes by a slight pressure, or when heated or much dried, being resolved into nitrogen gas and iodine.

ON SOME POINTS OF CHEMICAL THEORY.

The student has now advanced sufficiently far in practical knowledge of the phenomena of combustion, and of the properties of some acids, to render it expedient to present to him some general views of *combustion*, *acidity*, and *alkalinity*, and additional instruction on *classification* and *nomenclature*.

I am the more inclined to this course, as, among the compounds of nitrogen, there are three acids and an alkali.

Of Theories of Combustion.

Stahl supposed the existence, in all combustibles, of a common principle of inflammability, which he called phlogiston, from φλογιζω, to burn. He inferred that all substances, in burning, gave out phlogiston. The fallacy of this hypothesis is evident; since metals become heavier during combustion, obviously in consequence of the absorption of oxygen from the atmosphere.
cates of the phlogistic theory, nitrogen
with carbonic acid, and carbon with hy
both carbon and hydrogen were
phlogiston nearly pure; and

them, was supposed to become phlogisticated air, the name then given to nitrogen gas. It is now well known that with carbon, oxygen forms carbonic acid, with hydrogen, water; and that nitrogen gas contains neither carbon nor hydrogen.

Sulphuric and phosphoric acids, and metallic oxides, were severally supposed to be ingredients in the sulphur, phosphorus, and metals producing them. Thus of two bodies, that which was actually the lighter was assumed to contain the other.

The celebrated Lavoisier, to whom we are chiefly indebted for the exposure of these fallacies of the theory of phlogiston, having ascertained that oxygen is an indispensable agent in all ordinary cases of combustion, was erroneously led to infer that it was in all cases necessary to that process. But it is now well known that there are many instances of combustion, in which oxygen has no agency.

I would define combustion to be a state of intense corpuscular reaction, accompanied by an evolution of heat and light.

That increase or diminution of temperature consequent to chemical combination, which constitutes combustion when productive of heat and light, has been ascribed to a mysterious law, by which bodies undergo a change in their capacity to hold caloric. It has been supposed that the capacity of the compound is in some instances greater, in others less, than the mean capacity of the constituents; and that in the former case union is followed by an absorption of caloric, and of course by cold; in the latter, by the expulsion of caloric, and, consequently, the production of heat.

Yet, when the capacities of compounds are compared with those of their ingredients, the result does not justify the idea that the heat given out by the latter in combining, is produced by a diminution of capacity. At best, this hypothesis only substitutes one enigma for another; since it does not account for the alleged change of capacity.

The diversity of power to hold caloric in a latent state, technically designated by the word capacity, is now generally ascribed to the intervening influence of electricity. It has been shown that, if neighbouring bodies be electrified by means either of glass or resin, previously subjected to friction, they will repel each other; but that if one be thus excited by glass, and another by resin, attraction between them will ensue. Hence the excitements are considered of an opposite nature. It will be recollected that, according to the Franklinian theory, the vitreous excitement results from a redundancy, the resinous, from a deficiency of the electrical fluid. Hence Franklin designated the former as positive, the latter as negative electricity. By others, the different electric excitements are considered as the effects of two different fluids, attractive of each other, but self-repellent. The one has accordingly been called by them resinous, the other vitreous electricity. Yet, even by electricians who suppose the existence of two fluids, the terms positive and negative are employed.

It has been suggested that Voltaic phenomena, combustion, acidity, alkalinity, and chemical affinity, may owe their existence to the principle by which the different electric excitements are sustained in electrified bodies, modified in some inexplicable manner, so as to act between atoms instead of masses. This suggestion derives strength from the following facts, which have been fully illustrated in my lectures on electricity and galvanism.

The pole of a Voltaic series, terminated by the more oxidizable metal, has been shown to display a feeble electrical excitement, of the same kind as that which is producible by friction in glass; while the other pole displays the opposite excitement, in like manner producible in resin. From reiterated experimental observation it is now generally inferred, that, of any two substances chemically combined, and simultaneously exposed to wires proceeding from the Voltaic poles, one will go to the positive, the other to the negative pole. Atoms are supposed to have electrical states the opposite of those of the poles to which they may be attracted, and are said to be electronegative when attracted by the positive pole, and electropositive when attracted by the negative pole.

Substances which have opposite relations to the Voltaic poles, have an affinity for each other, which is usually stronger in proportion as the diversity of their electric habitudes is the more marked. Thus, for instance, oxygen which is pre-eminently electro-

and potassium which is pre-eminently electro-positive, have, under ordinary circumstances, a predominant affinity for each other. The power of the Voltaic wires, in severing such substances when combined, appears to be analogous to that exercised by atoms, which, by superior affinity, cause decomposition. But then there is this discrepancy, that the elements, after being attracted from each other by the wires, do not combine with *them*, as they do with the atoms which, by superior affinity, are productive of a similar decomposition. It would seem as if particles, separated from each other by the Voltaic pile, undergo successive changes in their electric states, which first paralyze their ability to remain in combination, and afterwards their susceptibility to the attraction of the poles; so that instead of adhering to them, they escape. Yet, even in this respect, there is greater analogy between chemical affinity, and that transiently exercised by the Voltaic poles, than at first view might be supposed; since the former power is found to be created, destroyed, altered, or even reversed by extraneous causes. Potassium, which, under ordinary circumstances, takes oxygen from iron or carbon, yields it to these substances at very high temperatures. Iron attracts oxygen from hydrogen in one case, yet relinquishes it to the same principle in another. The coherence of vegetable and animal fibres is obviously due to a cohesive power induced in the constituent ponderable atoms by the powers of vitality. The hempen cable which holds a ship of the line at anchor, is, by ignition, resolvable into water and charcoal. The deutoxide of hydrogen and oxide of silver, by mere contact and without any resulting union of their ponderable atoms, are converted explosively into water, oxygen, and silver.

By some philosophers, who ascribe the opposite electrical excitements to the influence of distinct fluids, it is conjectured that these fluids, when separated, become surcharged with heat and light, which they abandon on uniting. Hence when sufficiently accumulated and subsequently combined, ignition or explosion ensues, in consequence of the copious evolution of those imponderable principles. When these consequences result from the chemical reaction of ponderable particles, they are as- to the escape of heat and light arising from the of electric matter, previously forming a mean of combination with ponderable matter. That elec- y, in some mysterious mode, varies the power of erable substances to combine with each other, and tain heat and light in a latent state, seems to me y probable; yet I cannot consider any effort, hitherto , as successful in explaining how, consistently with own habitudes, it can operate to produce such won- l results.

reply to the hypothesis above stated, admitting the ence of two electric fluids to which there are great tions, it may be demanded, why is not cold produced the electricities are severed; if, under these circum- es, they abstract from the surrounding medium that arge of caloric which they relinquish on being re- d.

all sides it must be admitted that between chemical ion, galvanism, and electro-magnetism, there is an ate association which must be explained before the omena of combustion can be well understood.

has been mentioned that, of known bodies, oxygen roved the most electro-negative. It is questionable her the next place to oxygen is to be assigned to ine or fluorine. After these follow bromine, iodine, ur, selenium, and tellurium.

nong the metals we have a series of substances, ng from those in which the electro-positive power e-eminently great, as in potassium, sodium, lithium, m, calcium, magnesium, &c., to such metals as be- rather to the electro-negative class. Hence, setting rom the extreme abovementioned, we may proceed gh a long range of metals less and less electro-posi- till we arrive at such as produce electro-negative inations with oxygen or chlorine, or both. More or vithin this predicament, I think we find tin, mercury, platinum, palladium, antimony, arsenic, molybde- and lastly tellurium. Thus at an intermediate point een the extremes at which oxygen and the alkaligen ls are placed, there are substances whose electrical ion to the pile is equivocal or wavering; and it should derstood that this relation is always comparative. ine is electro-positive with oxygen and perhaps fluo- and electro-negative with every other body. Iodin is electro-positive with oxygen, chlorine, bromine, a probably fluorine, while with other substances it is el tro-negative.

Substances of the two opposite classes, in combin with each other, constitute compounds which are eit electro-positive or electro-negative, accordingly as the ferent energies of their ingredients preponderate. T in alkalies, consisting of oxygen united with the alk gen metals, the electro-positive influence predominat while the reverse is true of acids, consisting of the sa electro-negative principle, oxygen, in combination w sulphur, nitrogen, phosphorus, carbon, boron, silicon, se nium, or other substances, which, in their electrical ha tudes, lie between oxygen and those metals.

In some cases we see an electro-negative or elect positive power attached to compounds, which is not equa displayed by either of their constituent elements separat Cyanogen, consisting of carbon and nitrogen, is a strik instance of an electro-negative compound thus con tuted; and in ammonia, and the vegetable alkalies lat discovered, we have instances of electro-positive co pounds, produced from principles comparatively elect negative.

Of the Influence of the Habitudes of Chemical Agents u the Voltaic Series on Classification and Nomenclature.

It would follow from the statements made under last head, that there should be a resemblance between properties of substances which have a proximity to ea other in the electric series. Accordingly we find, a have already had occasion to state, that those which proach each other in the higher part of the electro-negat scale, have, by distinguished writers, especially in Gr Britain, been classed as *supporters;* while those which electro-positive, or feebly electro-negative, have been the same authors classed as *combustibles.* Also, cert electro-negative compounds, formed of the pre-emine electro-negative principles, have been associated as *aci* while other compounds, of oxygen at least, which have opposite polarity, have been associated as *bases,* under so of the subordinate divisions of alkalies, alkaline eart earths proper, or simply oxides. Pursuant to the vie upon which the basacigen class has been founded, the of electro-positive compounds should comprise other bodies besides oxides. Originally, acids owed their name and classification to the usual characteristic of sourness, of which, for a long time, none had been found deficient. This, however, can no longer be viewed as an indispensable characteristic of acidity.

The idea of a class of supporters of combustion and of combustibles, has no better foundation than that certain substances are more frequent agents in combustion. Thus hydrogen will produce fire with oxygen and chlorine only; sulphur with oxygen, chlorine, and the metals; and carbon with oxygen; but as either oxygen or chlorine will burn with a great variety of substances, they have been called supporters of combustion, and the substances with which they combine during combustion, combustibles. Iodine and latterly bromine have been classed among the supporters; because they combine with almost all the bodies with which the other elements classed under that name unite, and in some cases with an evolution of heat and light. Yet they are not gaseous like oxygen and chlorine, and are as analogous to sulphur as to oxygen. There appears to me to be an error in taking either of these substances into the class of supporters, while sulphur is excluded, which, next to oxygen and chlorine, has the property of burning with the greatest number of substances. In other respects sulphur seems, in its properties, to be intermediate between iodine and phosphorus. The habitudes of selenium appear to range between those of tellurium and sulphur.

Hydrogen, phosphorus, carbon, boron, and silicon are no more entitled to be called combustibles, than oxygen, chlorine, bromine, and iodine to be called supporters. It should be observed, also, that these appellations are evidently commutable according to circumstances; since a jet of oxygen, fired in hydrogen, is productive of a flame, similar to the inflamed jet of hydrogen in oxygen. If we breathed in an atmosphere of hydrogen, oxygen would be considered as inflammable, and of course a combustible. The arrangement which I have adopted of classifying as basacigen bodies, those which have heretofore been treated as supporters, with the addition of some others, renders it unnecessary to resort to the incorrect division into supporters and combustibles.

Of the Nomenclature of Oxides, Acids, and Salts.

It may be proper, before proceeding further in the study of the acids and oxides, to make the student acquainted with the meaning of certain terms and terminations, employed by chemists in designating those substances.

Where, in consequence of different degrees of oxidizement, substances form two oxides or two acids, one containing a larger, the other a lesser proportion of oxygen, the acid or oxide, having the lesser proportion, is distinguished by the name of the substance oxygenated, and a termination in *ous;* that containing the larger proportion of oxygen is designated in the same way, substituting *ic* for *ous;* as sulphur*ous* acid and sulphur*ic* acid, nitr*ous* and nitr*ic* oxide or acid. As respects oxides, however, these terminations have only been used in the cases adduced, and in that of carbon*ic* oxide. That ingredient in an acid or a base, which is least electro-negative, is called the radical. When an acid is discovered having less oxygen than one with the same radical, of which the name ends with *ous*, the word *hypo* is prefixed. Hence the appellations, *hypo*nitrous, *hypo*sulphurous. The same mean of distinction is employed to designate a degree of oxygenation exceeding that designated by *ous*, but less than that designated by *ic*. Hence the name *hypo*sulphuric. If there be an acid having still more oxygen than the one of which the name ends in *ic*, the letters *oxy* are prefixed.

Acids of which the names terminate in *ous*, have their salts distinguished by a termination in *ite*. Acids of which the names end in *ic*, have their salts distinguished by a termination in *ate*. Thus we have nitr*ites* and nitr*ates*, sulph*ites* and sulph*ates*. If the alkali be in excess, the word *sub* is prefixed, as *sub*sulphate. If the acid be in excess, *super* is prefixed, as *super*sulphate. The letters *bi* are placed before the name of salts having a double proportion of acid; hence carbonate and *bi*carbonate.

The oxide in which the oxidizement is supposed to be at the maximum is called the *per*oxide. This monosyllable, *per*, is also used in the case of acids, to signify the highest state of oxygenation, and has been improperly, as I conceive, substituted for *oxy* in the case of *per*chloric acid. Most chemists apply the monosyllable in question to distinguish a salt formed with a peroxide. Thus the red sulphate of iron has been called the *per*sulphate of iron. The nitrate of the red oxide of mercury, the *per*nitrate of mercury. Agreeably to a similar rule, salts formed with *proto*xides have the word *proto* prefixed; as in the instances of *proto*nitrate, *proto*sulphate, &c.

It has already been stated that by the British chemists the binary compounds of oxygen, chlorine, bromine, iodine, fluorine, and cyanogen, when not acid, are designated by the termination in *ide*. I have distinguished the binary compounds of all the basacigen bodies by appellations ending in *ide* excepting those which are acid. I should deem it preferable if this termination were considered as applicable to all compounds of the basacigen bodies, whether acids, bases or neutral, and that the terms acid and base should be considered as severally indicating the subordinate electro-negative, and electro-positive compounds. In that case *oxybase*, *chloribase*, *fluobase*, *bromibase*, *iodobase*, *cyanobase*, *sulphobase*, *telluribase*, *selenibase*, would stand in opposition to *oxacid*, *chloracid*, *bromacid*, *iodacid*, *cyanacid*, *sulphacid*, *selenacid*, *telluracid*. Yet for convenience, the generic termination *ide* might be used without any misunderstanding; and so far the prevailing practice might remain unchanged. Resort to either appellation would not, agreeably to custom, be necessary in speaking of salts or other compounds analogous to them; since it is deemed sufficient to mention the radical, as if the salt consisted of an acid combined with a radical, not an oxide. Ordinarily we say sulphate of lead, not sulphate of the oxide of lead. This last mentioned expression is resorted to, only where great precision is desirable. In such cases, it might be better to say sulphate of the oxybase of lead.

Of the Origin of the Idea of an Acidifying Principle.

At the period when the French nomenclature was adopted, oxygen was considered as the sole *acidifying principle*. Of course every acid being supposed to consist of oxygen in part, it was enough to call it an acid to convey a correct idea of its composition in that respect. But when, at a subsequent period, it was shown that many acids were destitute of oxygen, and that oth
stances were nearly as efficient as oxygen in
acids by a union with acidifiable bodies, it

sary to prefix syllables in order to distinguish the acid compounds produced by one acidifying principle, from those produced by others. The term acidifying principle originated with the error of assigning that character exclusively to oxygen. From convenience, more than any conviction of its propriety, it was afterwards used occasionally in reference to chlorine, hydrogen, and other elements which are found to produce acids by combining with a variety of substances.

It will be seen that there is no adequate reason for considering any element as an acidifying principle. The term *radical* originated at the same time, being the name given to the substances which oxygen was supposed to acidify. It has since been extended by me to all substances which form acids or bases with the *basacigen bodies*. After this explanation, the student will understand my meaning when I say that oxacids, or acids formed with oxygen, require no other designation than such as may indicate their radicals; whereas all other acids, in addition to the term formed from the radical, must have others prefixed, showing which of the basacigen substances constitutes their electro-negative principle. Thus in describing the acids formed by oxygen and chlorine with iodine, we have used the terms iodic and chloriodic; the first being equivalent in its import to an oxacid, or one in which oxygen is the electro-negative ingredient, the other indicating an acid in which, the radical iodine remaining the same, chlorine is the electro-negative ingredient.

Of Acidity and Alkalinity.

I conceive the following definitions to be justified by the practice of modern chemists in general, as established in the case of oxacids and oxibases. *When two compounds capable of combining with each other to form a tertium quid, have an ingredient common to both, and one of the compounds prefers the positive, the other the negative pole of the Voltaic series, we must deem the former an acid, the latter a base.* And again, all compounds having a sour taste, or which redden litmus, should be deemed acids in obedience to usage.

Acidity was originally synonymous with sourness, as it contin [illegible] e in colloquial language; but many substances are now called acids by chemists, which do not produce those effects. They are never, in fact, produced by such acids as the silicic and margaric acids, &c. which are insoluble in water. Solubility, however, notwithstanding these exceptions, is in general an attribute of the acids, and the great majority of them redden vegetable blues; yet sulphurous acid whitens litmus, and indigo is not reddened by any acid. Acids neutralize alkalies, and restore colours destroyed by them. Acids do not usually combine with acids, nor alkalies with alkalies, but acids and alkalies unite energetically with each other. I infer that alkalinity, acidity, and galvanic polarities have a common cause, perhaps in some appropriate combinations of the imponderable but material causes of heat, light, and electricity. To other combinations of these imponderable principles, the sweetness of sugar, the pungency of mustard and pepper, and the activity of certain vegetable poisons may be due. It is known that in morphia and strychnia, and in certain vegetable acids, the alkaline and acid properties are attached to ponderable elements, which exist in other compounds without inducing acidity or alkalinity.

COMPOUND OF NITROGEN WITH HYDROGEN.

Of Ammonia or the Volatile Alkali.

As substances which are analogous in their most important properties, are often utterly different in their composition, it is impossible to adopt any arrangement in treating of them, which may be in both respects satisfactory. The compound which is the subject of this article, was naturally associated with the other alkalies, when their composition was unknown; although now generally ranged with the compounds of nitrogen, whilst its former associates are placed among the metallic oxides.

Formerly, only three alkalies were known,—potash, soda, and ammonia. The two former, being difficult to vaporize, have been called *fixed alkalies*; the latter, being naturally aëriform, is denominated the *volatile alkali*. A new mineral fixed alkali was discovered in 1817, and named lithia. It was procured from a stone called Petalite. Hence its name from the Greek λιθειος, stony.

All the alkalies abovementioned have a peculiar taste, called alkaline. They all produce, in certain vegetable colours, characteristic changes, which differ according to the matter subjected to them, but are not varied by changing the alkali.

They restore colours changed by acids, and are capable of neutralizing acidity.

By their reaction with oils, soaps are generated, which are soluble in water.

There are certain metallic oxides which have been called earths, and which, in different degrees of intensity, have all the alkaline properties abovementioned, excepting the last.

There are also some vegetable compounds which possess, to a sufficient extent, the attributes of alkalies, to be classed among them.

According to Bonsdorf, the halogen elements of Berzelius produce bases, which in some cases display alkalinity. He has noticed a change of colour, indicating an alkaline reaction, on litmus paper, reddened previously by an acid, and dipped into a solution of the chloride of calcium, magnesium, or zinc.

It is my intention, as introductory to the subject of ammonia, to adduce a few experiments which illustrate the properties of alkalies in general.

215. *Experimental Illustrations of the characteristic Effects of the Alkalies on certain Vegetable Colours.*

Into infusions of turmeric, alkanet, Brazil wood, and rhubarb, a few drops of solutions of either of the alkalies being introduced,—turmeric, from a bright yellow, becomes brown, rhubarb, from nearly the same yellow, becomes red. Brazil wood, from a light red, becomes violet-red, and alkanet, from red, becomes blue. Acids being added, the colours are restored, but by a sufficient quantity of alkali are changed, as in the first instance, and by acids again restored; so that the experiment may be repeated several times with the same infusions.

A blue infusion, obtained from red cabbage, is rendered green by an alkali. By adding some acid, the blue colour is restored; by a further addition of the acid, the infusion becomes red. An alkali being next introduced, it becomes blue, and by a further addition of alkali, the green colour reappears. By alternately using acids and alkalies, these changes may be repeated several times.

The power of various acids in reddening infusions of litmus, shown; and, subsequently, the restoration of the blue colour by an alkali.

Preparation of Ammonia.—Ammonia is obtained from sal ammoniac, the salt from which it received its name.

To evolve this alkali in the gaseous state, equal parts of sal ammoniac and quicklime, both finely pulverized, are to be heated gradually in a glass matrass. The ammonia is partially extricated by the mere mixture of the materials; but heat is necessary to complete the operation.

Sal ammoniac, according to the opinion generally entertained, is a compound of chlorohydric or muriatic acid and ammonia. The lime having a greater affinity for the acid than the ammonia, by simple affinity combines with it, and liberates the alkali as a gas, the state which it naturally assumes when isolated.

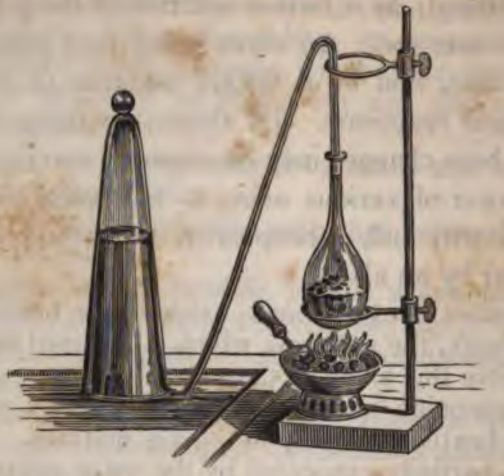
A different view of this subject is taken by Berzelius, which will be explained when treating of ammonium.

When it is an object to have the gas perfectly free from humidity, it is necessary to arrest the process as soon as moisture begins to condense in the neck of the receiver; or to interpose, between the neck, and the recipient used to receive the gas over mercury, a tube containing dry hydrate of potash in small fragments.

216. *Experimental Illustration of the Process for obtaining Gaseous Ammonia.*

A flask, containing equal parts of quicklime and sal ammoniac, both well pulverized and thoroughly intermingled, is exposed to as much heat as the glass will bear.

A bell glass is so placed over the mercurial cistern, as to receive any gas which may pass from the orifice of a tube, luted at one end into the flask charged with the materials, and at the other entering the mercury so as to be under the bell. This apparatus is represented on the next page.



Properties of Ammonia.—Ammonia acts like an upon the organs of taste, upon vegetable colours, a neutralizing acidity. When present in the air only i nute proportion, it is agreeably stimulating to the but otherwise it is intolerable to the eyes and orga respiration. Its specific gravity is 0.5897, and 100 inches weigh 18.28 grains. It is not inflammable i air, yet inflames with chlorine spontaneously, and oxygen, by the aid of an electric spark, or galvanic tion. A candle flame is at first enlarged and after extinguished by immersion in this gas. Water ab it with surprising velocity, and will hold from 450 t times its bulk.

Ice melts in it more speedily than in a fire.

Heat either decomposes, or volatilizes, all ammon compounds; and either of the fixed alkalies, or o three more powerful alkaline earths, disengage it any of the acids.

Ammonia, by refrigeration alone, may be cond into a liquid at —40° F. By a pressure of six at pheres and a half, Mr. Faraday succeeded in liquefy at the temperature of 50° F.

217. *Experimental Illustrations.*

Sal ammoniac and quicklime, being powdered, mixed in small glasses, pungent fumes are emitted.

a extricated by the process above described, an lected in bell glasses over mercury. The introduction of a few drops of water causes the gas to disappear. Ice, in the same way introduced, is liquefied, and causes a like result. Characteristic changes effected in the colour of water, tinctured by turmeric, alkanet, Brazil wood, and rhubarb.

Evolution of gas shown by means of potash and an ammoniacal salt, introduced into a glass vessel over mercury.

Equal volumes of ammonia and chlorohydric acids, mixed, and condensed into a solid, constituting sal ammoniac.

A mixture of ammonia with oxygen gas, exploded.

Of the Composition of Ammonia.

According to Berzelius, ammonia was first ascertained to be a compound of nitrogen and hydrogen by his celebrated countryman, Scheele. At a later period, Berthollet ascertained the ratio in which these substances exist in it, which is by volume that of three of hydrogen to one of nitrogen, condensed into two volumes; and by weight, 3 of hydrogen to 14 of nitrogen. See Table, page 236.

The partial decomposition of ammonia may be effected by subjecting it to a succession of electrical sparks. Each spark causes the decomposition of a portion of the gas; but as the process proceeds, it becomes more difficult, so that a complete decomposition is impracticable. That portion which is decomposed, is doubled in volume; since the three volumes of hydrogen and one of nitrogen occupy, while combined, but half of the space which they would fill if uncombined.

Ammonia, by being made to pass through tubes at a red heat, is resolved into its constituents. This result is promoted by the presence of metallic wire. Any metal will have more or less effect, but iron is most efficacious. It appears from recent experiments of Despretz, that this metal, by continued exposure, may be made to take up nearly twelve per cent. of its weight, becoming a nitruret by the absorption of the nitrogen of the ammonia. It is supposed that other metals, which, after a like exposure, exhibit no increase of weight, receive and abandon nitrogen alternately; an operation which appears to be singular and mysterious. The metals become brittle during this process. Probably their influence is in its nature electro-chemical. In its effects it appears to be the reverse of that by which the union of the elements of water is promoted by the presence of some metals in a state of minute division.

The decomposition and analysis of ammonia have been attempted by ignition with oxygen gas. I have often caused them to inflame by means of a wire ignited by galvanism. I believe it to be almost impracticable to ascertain the result accurately by measurement, on account of the liability of ammonia to be absorbed by the moisture of the apparatus, the water produced by the combustion, and the mercury employed to con gases.

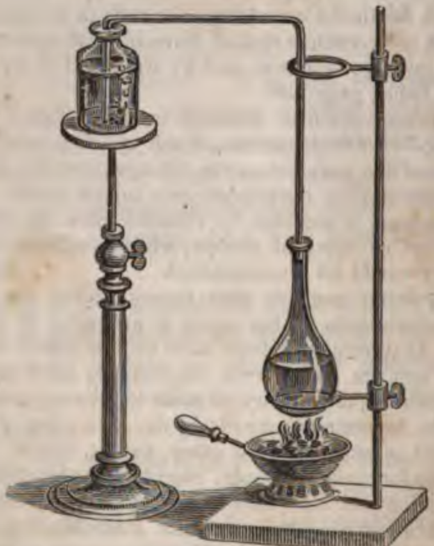
A spontaneous and explosive combustion ensues between chlori the hydrogen of gaseous ammonia. When chlorine is passed in through concentrated liquid ammonia, a reaction takes place with s noise, as apparently to endanger the containing vessel.

This process has already been mentioned as one of the means of ing nitrogen.

In its reaction with ammonia iodine differs from chlorine. Whe is brought in contact with dry ammoniacal gas, it forms a thic fluid, which, when saturated with ammonia, becomes more liquid. compound is decomposed by water forming the iodide of nitroge page 243.

With various metallic oxides, ammonia forms explosive com especially those known as fulminating gold, and the most danger cies of fulminating silver. By these appellations, however, othe pounds of those metals are designated. By some mysterious in probably electro-chemical, the affinities between the oxygen and hy are suspended without being destroyed. Yet by slight causes, mechanical or chemical, the equilibrium is subverted with explos lence.

218. *Process for obtaining Water of Ammonia.*



If instead of being conveyed into a bell glass ove cury, the gas be received in water contained in a the water may be saturated, constituting aqua ammo water of ammonia. The saturation may be effected us, similar to that represented in the above absorption of ammoniacal gas by water, ich heat, that, to produce a saturated solution, re-ıtion by ice-water is necessary.

ıter, saturated with ammonia, when gradually cooled temperature of — 40° F., crystallizes in long nee-aving a silky gloss. No doubt these crystals owe existence to the presence of water, which exists in as water of crystallization. Water of ammonia is than water. In combining with the gas, the water weight in proportion to the degree of impregna- At the maximum, at ordinary temperatures, the al-onstitutes about one-third of its weight.

Of Ammonium.

well known that Davy resolved potash and soda severally into me-oxygen, by exposing those alkalies to the divellent influence of aic current. Subsequently, Berzelius, not having at command an ıs sufficiently powerful, when unassisted, to effect this decomposi-certained that, by placing mercury in contact with a moistened cali, and in communication with the negative pole, while the alkali iicated with the positive pole, an amalgam would result either of m or sodium, according to the alkali employed.

results, when ammonia is subjected to the galvanic circuit in con-ı mercury at the negative pole, having a perfect analogy, as re-ıe production of an amalgam, with those obtained by a similar ex-ıf the other alkalies, as above mentioned, led naturally to the in-that the causes were analogous; and that, in the case in question, han in the others, a metallic radical had been deoxidized and united mercury. This inference was rendered more plausible by the ı of oxygen at the positive pole during the formation of the amal-Yet ammonia was known to consist of hydrogen and nitrogen; and ler either or both of these as oxides, was inconsistent with all the ge otherwise obtained respecting them. By some chemists, how-rogen was conjectured to be the oxide of a metal, with which this ı was supposed to be formed. For this supposed metal, the name *um* was suggested. Hence the contact of the amalgam with water ıceived to cause the absorption of oxygen by the nitricum, and ently the extrication of hydrogen.

Lussac and Thenard explained the formation of the amalgam, by g the absorption of ammonia by the mercury, together with a por-ydrogen derived from the simultaneous decomposition of water.

lius admits the fact of the union of the elements of ammonia and n with the mercury, in the proportions alleged by the distinguished hers above named; but conceives that, by the addition of an atom ogen to the ammonia, this alkali is converted into a metal, which *ammonium.* To the union of this metal with mercury, he as-ıe production of the amalgam; and to a resolution of the metal lements, the evolution of the ammonia and hydrogen. When an ammonia is presented to an atom of water, he infers that the hy-ıf the water converts it into ammonium, which is simultaneously by the oxygen. Hence an atom of ammonia, when combined with an atom of water, may be considered as acting as an oxybase of ammonium. When gaseous ammonia is presented to chlorine, one portion of it is decomposed, of which the nitrogen is liberated, while the hydrogen converts another portion into ammonium. This forms with the chlorine a *chloride of ammonium*, and, accordingly, by this appellation, sal ammoniac, or muriate of ammonia, must be designated, agreeably to the hypothesis under consideration.

When in the process, already given for obtaining ammonia, chloride of ammonium (sal ammoniac) is mingled with the oxide of calcium (lime,) by double elective attraction, the chlorine combines with the calcium, and the oxygen with one atom of the hydrogen in the ammonium; so that water and ammonia are evolved. The latter assumes the gaseous form, while the water unites with the chloride, and remains in union with it, if the heat be not raised unnecessarily, and continued too long.

If we attempt to decompose ammonia without the assistance of mercury, it yields nothing but hydrogen and nitrogen; yet, to produce the amalgam, it is sufficient that the wire employed be coated with mercury. The globule of mercury which is left after the spontaneous decomposition which the mass sustains, is in volume often not more than the two-hundredth part of that of the amalgam.

The most elegant mode, says Berzelius, of obtaining the ammoniacal amalgam, is to place a globule of the amalgam of potassium in a cavity of a piece of chloride of ammonium, slightly moistened. The globule soon enlarges to many times its previous dimensions, by the absorption of the ammonium, which relinquishes its chlorine to the potassium.

The ammoniacal amalgam, agitated in dry atmospheric air, yields hydrogen and ammoniacal gas. The same gaseous substances are extricated from it when plunged into ether or naphtha. The ammoniacal amalgam may be preserved for some time, if surrounded by hydrogen.

Berzelius does not consider ammonia as capable of becoming a base, without first being converted into ammonium by the acquisition of hydrogen. In this state, without further change, it can, like other metals, form salts by combining with any of the halogen substances. But to combine with oxacids, the ammonium must, like other metals, be oxidized. The presence of water at once metallizes and oxidizes ammonia. The hydrogen converts the ammonia into the metal, and the oxygen converts that metal into an oxide.

When gaseous ammonia precipitates, from an aqueous solution of a haloid salt, a metal in the state of oxide, water is decomposed, the hydrogen converting the ammonia into the metal ammonium, while the oxygen converts the metal into an oxide. Meanwhile, the ammonium, combining with the halogen element of the haloid salt, takes the place previously occupied by the metal which has been oxidized.

219. *Experimental Illustrations.*

In a cavity, made in a bit of muriate of ammonia, in communication with one of the poles of the Voltaic pile, a moistened globule of mercury is supported. The mercury is made to communicate with the other pole. The metal swells rapidly, and assumes all the characteristics of an amalgam.

An amalgam of potassium, being introduced into a cavity in a piece of sal ammoniac, is rapidly converted into the ammoniacal amalgam, with a prodigious enlargement in bulk.

* * *

SECTION III.

OF PHOSPHORUS.

Preparation.—Phosphorus is obtained from the phosphate of soda in urine, or the phosphate of lime in bones.. Impure phosphoric acid may be extricated from the earth of bones, by the stronger affinity of sulphuric acid. As, at a high temperature, charcoal takes oxygen from phosphorus, the phosphoric acid is decomposed by ignition with it in a retort, the beak of which is so introduced into water, as to have the orifice a little below the surface. Phosphorus distils into the water, and condenses in tears.

Agreeably to another process, the phosphate of soda, which may be procured at the shops, is decomposed by nitrate of lead, by complex affinity. The phosphorus is separated from the resulting phosphate of lead, by distillation with charcoal, as in the process above mentioned.

Properties.—Phosphorus is often of a light flesh colour, but when pure is colourless and translucent. It is rather harder than wax, but is more easily divided by a knife.

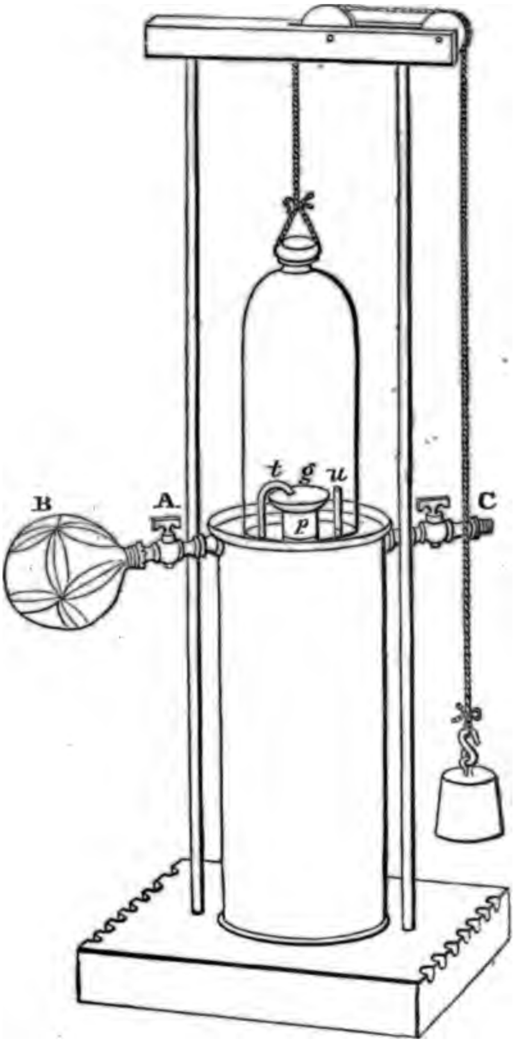
Phosphorus is insipid and probably inodorous; but, in consequence of its oxidizement, it emits a feeble alliaceous odour of phosphorous, or hypophosphoric acid. When pure it is flexible, but the presence of $\frac{1}{600}$th of sulphur renders it brittle. Its specific gravity is 1.77. Subjected to the rays of the sun, it acquires a red colour. If heated to 155° and suddenly cooled, it becomes black. Thenard, however, states that this change ca f fected in phosphorus which has not been rep tilled. He suggests it as possible, that th phosphorus, when pure, is black; and that the colour which it usually assumes, may be due to the presence of hydrogen, which has been long known to be evolved, when phosphorus, in the usual state, is fused and subjected to the Voltaic current.

Exposed to the air at ordinary temperatures, phosphorus combines slowly with oxygen, appearing luminous in the dark, but without any sensible evolution of heat. Less heat is requisite to cause the inflammation of phosphorus in atmospheric air than in oxygen; and less also is necessary in this last mentioned gas, in proportion as the pressure is reduced. Phosphorus melts at 108°, and inflames at 148°. At 550° it boils, and may be purified by distillation from a retort filled with hydrogen gas, receiving the product under water.

When sprinkled with powdered sulphur, carbon, fluoride of calcium, carbonate of lime, and various other bodies, and placed in a receiver from which the air is subsequently exhausted, phosphorus inflames. Professor A. D. Bache, who has much enlarged the list of substances capable of producing this result, has succeeded in inflaming phosphorus in an exhausted receiver by enveloping it in muslin, or in paper pierced with small holes. He conceives that, with the exception of bodies exercising a chemical affinity, as in the instance of sulphur, the substances associated with the phosphorus act mechanically, and have upon it no other effect than that of promoting its union with the oxygen remaining in the receiver. This opinion is corroborated by the fact that the removal of the air may be too rapid, or too complete, to produce the inflammation.

Phosphorus may be crystallized from its solution in boiling naphtha, by gradual refrigeration. Like sulphur, phosphorus, in volatilizing, produces a feeble light, without entering into any chemical combination. Water in which phosphorus has been kept, oxygen being excluded, acquires the power of shining when agitated. The admission of air destroys this phosphorescent property. Phosphorus is oxidized by the action of nitric or nitroso-nitric acid, and converted into phosphoric acid.

Combustion of Phosphorus in Nitric Oxide.



220. *Experimental Illustrations of the Properties of Phosphorus.*

Phosphorus exhibited, and inflamed by friction or a entle heat. Luminous appearance in the dark. Comustion in oxygen, and in nitrous and nitric oxide.

Anomalous combustion of phosphorus consequent to refaction.

221. *Combustion of Phosphorus in Nitric Oxide.*

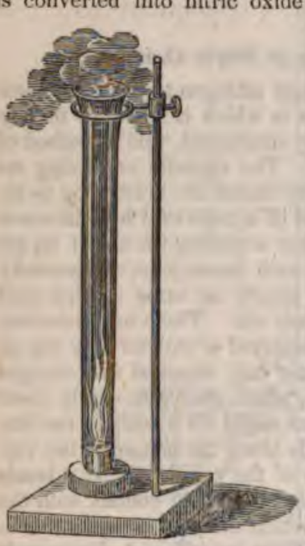
The backwardness of the gaseous oxides of nitrogen to part with their ygen to substances, under circumstances in which it would be readily elded by atmospheric air, has been already mentioned, and a method of ustrating it has been described, page 227. The opposite engraving reesents an apparatus, which may be used to extend the illustration to nic oxide, which, producing a corrosive fume of nitrous acid by admixture ith oxygen, cannot be employed in apparatus requiring the aid of an air mp, without corroding the metal of which such instruments are partially nstituted. The apparatus in question is nearly the same as that used r the separation of nitrogen from atmospheric air. There are, however, this, two additional tubes; and the bell employed is without any cap or ck. The cock at A, to which a gum elastic bag, supplied with oxygen s, is attached, communicates with a pipe, which descends within close ong the inner side of the cylindrical copper vessel till it reaches the botm, then bends at right angles, and proceeds along the bottom of the vesl till it reaches the copper pipe in the axis of the vessel. Next it bends right angles upwards, and ascends vertically in close contact with the pe, till it reaches the copper cup, *g*, by which the pipe is surmounted. is there so recurved as to overhang and direct its orifice, *t*, downwards to the cavity of the copper cup.

Another tube, *u*, proceeds from its junction with a screw and cock, C, n the other side of the vessel, and descends to the bottom, rising again, ke the tube above-mentioned, along the central pipe, till it reaches somehat above the brim of the cup, where it terminates without a curvature. fter the proper quantity of phosphorus have been placed in the cup, the tmospheric air may be allowed to escape from the bell glass through the ock, C, by sinking it into the water, with which the vessel must have een filled nearly to the brim. The air being expelled, and a communicaon made with a self-regulating reservoir of nitric oxide, by means of the exible leaden tube attached to the cock for that purpose, the bell may be upplied with a quantity of this gas, sufficient to occupy about two-thirds f its capacity. The cock being then closed, and the communication with e reservoir interrupted, a red-hot iron must be introduced through the ore of the central pipe, *p*, till it touches the cup. For this purpose, it is f course necessary that the apparatus should be upon a table with a suitle aperture, and of a height sufficient to allow the iron to enter the orie of the pipe, *p*.

Although by the heat of the incandescent iron, the phosphorus will be ed, no combustion will ensue, until, by opening a communication with gum elastic bag, a small quantity of oxygen is allowed to enter. But no sooner is this permitted to take place, than a most brilliant and almost explosive evolution of heat and light ensues. A higher temperature is requisite to ignite phosphorus in nitric than in nitrous oxide.

222. *Reaction of Phosphorus with Nitroso-nitric Acid.*

If into a tall tube of about an inch and a half in diameter, and fifteen inches in height, some strong nitric acid be introduced, and about five grains of phosphorus, a reaction will ensue, which is invariably energetic, and sometimes explosive. The phosphorus abstracting oxygen, the acid is converted into nitric oxide gas and nitrous acid vapour, which are copiously evolved, so as to fill the upper part of the tube, and overflow it with a beautiful red fume. Meanwhile, vivid flashes arise from the oxygenation of the phosphorus, and pieces of it are occasionally thrown up into the gas in the tube, where a vivid combustion ensues between the phosphorus, and the oxygen of the nitric oxide gas or nitrous acid.



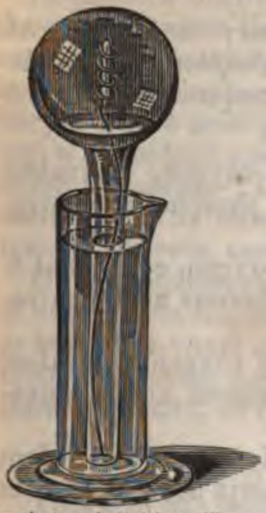
The residual nitric acid will be found intermingled with phosphoric acid.

Latterly, in performing this experiment, I have surrounded the tube with a very stout glass cylinder, and another of wire gauze; as upon one occasion a violent explosion took place, which did much damage to my apparatus. If the phosphorus be reduced into small fragments, the risk of an explosion is increased. Heating the acid, before the addition of the phosphorus, ensures an explosive reaction.

Application of Phosphorus to Eudiometry.

One of the most simple modes of ascertaining the quantity of oxygen in the air, is to introduce into a graduated tube, standing over water, and containing 100 measures of air, a stick of phosphorus, supported by a wire. The phosphorus slowly dissolves in the nitrogen, and, combining with the oxygen, condenses with it, and causes a corresponding absorption of the water. When, by these means, the oxygen is all removed, the quantity of nitrogen remaining will be known by inspecting the graduation. The difference between this quantity and 100, the number of measures taken, is the quantity of oxygen present.

223. *A Simple Atmospheric Eudiometer by Phosphorus.*



If a cylinder of phosphorus be supported upon a wire (as represented in the adjoining cut,) within a glass matrass, inverted in a jar of water, the oxygen of the included air is gradually absorbed. In order to determine the quantity of oxygen in the air, we have only to ascertain the ratio of the quantity of gas absorbed, to the whole quantity of air included in the matrass at the commencement of the process.

This object may be attained by weighing the matrass when full of water, and when containing that portion only which rises into it in consequence of the absorption. As the weight in the first case is to the weight in the last, deducting the weight of the glass in both cases, so will 100 be to the number of parts in 100 of atmospheric air, which consist of oxygen gas.

Again, the contents of the vessel may be discovered by the sliding rod gas measure, page 225, and the absorption measured by introducing from the same instrument, as much air as will compensate it. As the whole content to the quantity which compensates the absorption, so is 100 to the quantity of oxygen in 100 parts of the atmosphere.

If the neck of a vessel of this kind hold about one-fourth as much as the bulb,—by graduating the neck, so that each division will represent a hundredth part of the whole capacity, the result may be known by inspection.

Eudiometrical processes by the slow combustion of phosphorus are tedious, requiring many days to complete them, and consequently the aid of barometrical observations to ascertain and allow for any intervening changes in atmospheric pressure.

It is alleged that nitrogen is enlarged one-fortieth of its bulk, by the phosphorus which it dissolves. This is to be deducted in estimating the residual gas.

The action of the phosphorus may be accelerated by heat; but in that case the operation must be performed over mercury; and the manipulation will be found troublesome and precarious.

224. *Volumescope for the Analysis of Atmospheric Air by Phosphorus.*

At page 232, article 208, a volumescope is described for showing the diminution of bulk in five volumes of atmospheric air, consequent to the admixture of nitric oxide.

The same apparatus may, with some modification, be employed to show the diminution of volume resulting from the combustion of phosphorus. This object is effected by associating with the volumescope, the apparatus employed for the combustion of phosphorus in oxygen, page 157, article 157. For this purpose the volumescope, instead of being situated over the pneumatic cistern, should be placed in a small tub, into the bottom of which is inserted a tube, supporting, at the upper extremity, the cup for the phosphorus. The phosphorus being placed in the cup, and water in the tub, this liquid is raised by an air pump, until no more than five volumes of air remain in the cylinder.

The phosphorus is then ignited by means of a red-hot iron, and the process conducted as already described, page 217, article 194.

As soon as the expansion resulting from the heat of the combustion ceases, it will be seen that a little more than one volume out of the five has been condensed.

COMPOUNDS OF PHOSPHORUS WITH OXYGEN.

These compounds are four in number; one oxide, *oxide of phosphorus*, and three acids, *hypophosphorous*, *phosphorous*, and *phosphoric acid*. Their composition is as follows:—

Three atoms of phosphorus, equivalent 48,	with one atom of oxygen, equivalent 8, form oxide of phosphorus, equivalent 56.
Two atoms of phosphorus, equivalent 32,	with one atom of oxygen, equivalent 8, form hypophosphorous acid, equivalent 40.
	with three atoms of oxygen, equivalent 24, form phosphorous acid, equivalent 56.
	with five atoms of oxygen, equivalent 40, form phosphoric acid, equivalent 72.

Of Oxide of Phosphorus.

When phosphorus, melted under hot water, is subjected to a jet of oxygen from a tube with a capillary orifice, oxide of phosphorus and phosphoric acid are produced. The acid dissolves, and the oxide, being at first suspended in the water, subsides subsequently in red flakes. This oxide is insipid and inodorous. It is not luminous in the dark, even when rubbed. At a heat a little below redness in close vessels, it is decomposed into phosphoric acid and phosphorus. If the air be admitted, phosphoric acid is the sole product. The oxide of phosphorus takes fire spontaneously in chlorine, producing the perchloride of phosphorus and phosphoric acid. It is inflamed by the action of nitric acid. With chlorate of potash it explodes violently: also with nitrate of potash previously warmed. The white matter with which phosphorus becomes coated when kept in water, and which is generally supposed to be a hydrate of the oxide, is stated by Thenard to be a hydrate of phosphorus.

225. *Production of Oxide of Phosphorus experimentally illustrated.*

Production of oxide of phosphorus, by the reaction of oxygen with the substance, while in fusion under hot water.

Of Hypophosphorous Acid.

[This acid may be formed by the action of water on the phosphuret of barium. By a new arrangement of the reacting elements, there become formed phosphuretted hydrogen, phosphoric and hypophosphorous acid, and baryta. The acids generated unite with the baryta, forming a phosphate and hypophosphite, the latter of which alone is soluble. The hypophosphite of baryta is then decomposed by means of sulphuric acid, which precipitates the baryta, and sets the acid free.

Hypophosphorous acid, as thus obtained, is in the form of an aqueous solution, which may be concentrated so as to become a viscid liquid, highly acid and even crystallizable. This acid is a powerful deoxidizing agent. It forms numerous salts, all of which are soluble in water.] 6, 240

Of Phosphorous Acid.

This acid has been generally considered as the product of the slow combustion of phosphorus with atmospheric oxygen; but Thenard alleges that this product is a peculiar acid, intermediate in its degree of oxidation between phosphorous and phosphoric acid, and to which he has given the name of *hypophosphoric acid*. Phosphorous acid may be procured by passing vaporized phosphorus over corrosive sublimate heated in a tube. Chloride of phosphorus results, which, by reaction with water, produces chlorohydric and phosphorous acids. The chlorohydric acid, being more volatile, may be expelled by heat.

Phosphorous acid is a colourless, inodorous, crystalline substance, possessing a pungent taste, and reddening litmus paper. Like hypophosphorous acid, it possesses powerful deoxidizing properties. – 56

Of Phosphoric Acid.

Preparation.—Phosphoric acid may be obtained by adding sulphuric acid to phosphate of baryta, suspended in water. The sulphuric acid unites with the baryta, forming an insoluble salt which precipitates, while the phosphoric acid remains in solution. When phosphorus is gradually added to nitric acid, phosphoric acid is generated, and remains mingled with the residual nitric acid.

Properties.—Phosphoric acid is an inodorous, colourless, viscid liquid, possessing in a high degree the property of reddening litmus. It cannot be obtained free from water. When exposed to a red heat and afterwards cooled, it forms a transparent brittle glass. This fusion should be effected in a platinum crucible; since phosphoric acid, when heated to redness, attacks either glass or porcelain. The acid, if examined after this exposure to heat, is found, although its composition remains the same, to have acquired new properties. On this account, the name of *paraphosphoric* has been given to it; while the term phosphoric is applied to designate the acid in the state first described. Nitrate of silver yields with phosphoric acid a yellow precipitate; with paraphosphoric acid a white one. Albumen is coagulated by the latter, but not by the former.

Solid paraphosphoric acid, when exposed to the air, deliquesces, and is in a few days converted into phosphoric acid. The same change is produced in a short time by boiling water. The solid white flakes which are obtained during the quick combustion of phosphorus with oxygen, consist of paraphosphoric acid. It may likewise be produced by fusing the biphosphate of soda, which by these means is converted into a paraphosphate. Mr. Graham, who has made a number of interesting experiments on this subject, states that the acid which is contained in fused phosphate of soda, is a third species of phosphoric acid, which coincides in composition with the others, but not in properties. To this species he has given the name of *pyrophosphoric acid*.

To bodies which possess different properties, while containing the same number of atoms of the same elements, and having the same atomic weight, the term *isomeric* has been applied. Thus, phosphoric, paraphosphoric, and pyrophosphoric acids are said to be isomeric bodies.

Σ72

Of the Chlorides of Phosphorus.

It has been shown, article 163, that phosphorus burns spontaneously in chlorine. If the chlorine be in excess, the perchloride is formed; if the phosphorus be in excess, the sesquichloride is obtained. The *sesquichloride* is a transparent, colourless, fuming, inflammable liquid, heavier than water, and having a disagreeable smell. When brought into contact with water, a reciprocal decomposition takes place, and chlorohydric and phosphorous acid are produced. The *perchloride* is a white, crystalline, inflammable body, which is converted into vapour at a temperature much below 212°. It forms a neutral compound with ammonia, and its vapour is alleged to redden dry litmus paper. Hence, by some chemists, it is considered as an acid. I doubt whether litmus paper is ever reddened by an acid, unaided by water. The perchloride and water decompose each other, forming phosphoric and chlorohydric acid. The chlorine bears the same ratio to the phosphorus in these chlorides, as the oxygen bears to the phosphorus in phosphorous and phosphoric acid.

Of the Bromides and Iodides of Phosphorus.

The *sesquibromide* is a yellow fuming liquid; the *perbromide*, a crystalline volatile solid. In their reaction with water and composition, they agree with the chlorides of phosphorus. Iodine appears to combine with phosphorus in almost every proportion. There are, however, at least two definite combinations, which correspond in composition with the chlorides and bromides.

Of the Sulphides and Selenides of Phosphorus, commonly called Sulphurets and Seleniurets.

When phosphorus is melted with sulphur, or when sprinkled with it, and placed in a receiver from which the air is subsequently withdrawn, (see page 262,) a sulphide of phosphorus is formed. This sulphide may consist of various proportions of its ingredients, according to the circumstances under which it is produced. Sometimes it is liquid, sometimes solid.

Selenium, like sulphur, combines with phosphorus in almost every proportion. The sulphides and selenides of phosphorus are decomposed by water.

The incorporation of sulphur with phosphorus, when effected by heat, is sometimes productive of explosion; and the resulting mass is spontaneously inflammable in the air.

COMPOUNDS OF PHOSPHORUS WITH HYDROGEN.

Of Protophosphuretted Hydrogen.

Protophosphuretted hydrogen may be obtained by heating a concentrated solution of phosphorous acid, or by adding phosphorus to the materials for generating hydrogen.

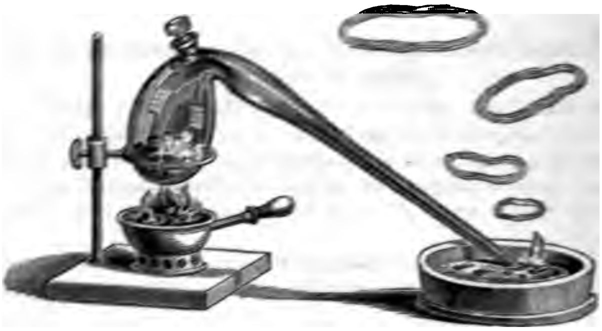
Properties.—It is a colourless, inflammable gas, with an odour similar to that produced by the combustion of arsenic. Under the ordinary pressure of the atmosphere, protophosphuretted hydrogen does not inflame spontaneously with oxygen; but, if the pressure be reduced about one-third, combustion ensues.

On meeting with oxygen, this gas becomes luminous in the dark, in consequence of the slow combustion of the phosphorus: though the heat evolved is inadequate to inflame the hydrogen. If the process for producing the philosophical candle, described in article 176, be repeated with the addition of comminuted phosphorus to the materials, protophosphuretted hydrogen will be generated, and, escaping into the air, will produce a jet luminous in the dark.

Of Perphosphuretted Hydrogen.

Perphosphuretted hydrogen may be produced by the reaction of chlorohydric acid with the phosphuret of calcium, which is obtained by subjecting lime to the vapour of phosphorus at a bright red heat in a porcelain or coated glass tube. The gas may also be evolved by heating in a retort, 75 grains of phosphorus, 1500 of slaked lime, with 4 ounces of water; or 50 grains of caustic potash, and 40 of phosphorus, moistened by drops of water. The phosphorus should be added first, and the potash last; as the heat which it evolves, contributes to the heat required for the operation. The body of the retort should be filled with hydrogen, or a few drops of ether should be added, to prevent the first portions of the gas from inflaming with the atmospheric oxygen of the retort. By its affinity for the phosphorus, and the metal of the phosphuret, the oxygen of the water is separated from the hydrogen, which, while nascent, unites with a portion of the phosphorus, and forms perphosphuretted hydrogen.

The following cut represents the apparatus usually employed for obtaining perphosphuretted hydrogen.



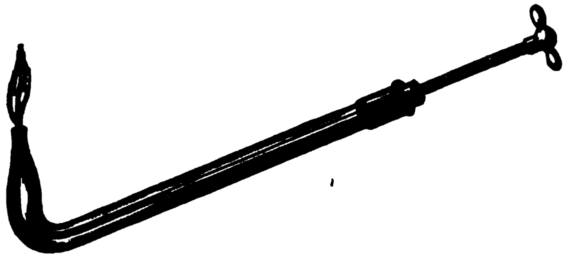
The beak of the retort being depressed below the surface of the mercury, each bubble, as it escapes into the atmosphere, explodes. It produces at the same time a dazzling flash, which is transformed into a beautiful wreath of smoke, consisting of aqueous vapour and phosphoric acid created by the oxygenation of the hydrogen and phosphorus. Each wreath, as it rises, expands in diameter, and, when the bubbles succeed each other quickly, a series of them may be seen in the air at the same time.

Properties.—Perphosphuretted hydrogen is a colourless gas, possessing an alliaceous smell, and a bitter taste. Water dissolves it in small quantity, forming a yellow solution, which has a bitter taste, and a smell resembling that of the gas. When this gas is brought in contact with oxygen, or atmospheric air, it explodes with a loud noise and a vivid flash; being converted into phosphoric acid and water. The same mixture, in narrow tubes, undergoes a similar chang[illegible]ly, and without the evolution of heat and light.

Perphosphuretted hydrogen may be decomposed either by heat, by the electric spark, or by the rays of the sun. Professor Rose considers protophosphuretted and perphosphuretted hydrogen as isomeric, and of course similar in composition, though different in properties. If the opinions of Rose are correct, one should be called phosphuretted hydrogen, the other paraphosphuretted hydrogen. See article on phosphoric acid, page 267.

Chemists do not agree in their statements respecting the composition of the compounds of hydrogen with phosphorus.

226. Method of exhibiting the Inflammation of Small Portions of Gas.



This figure illustrates an advantageous employment of the sliding rod eudiome- r, in exhibiting the spontaneous combustion of phosphuretted hydrogen, the lendid colour of the flame of cyanogen, and other experiments, where the com- istible character of a small quantity of gas is to be shown.

For the experiments in question, the instrument is charged, agreeably to the mode ready described in the case of the eudiometers, by introducing the apex into any ll glass or other vessel holding the gas, and drawing out the rod; by which a rtion of the gas, equivalent in bulk to the part of the rod withdrawn, enters the ceiver of the eudiometer through the hole in the apex.

The receiver being then removed from the bell glass, and held up in a position vourable for observation, the rod is slowly returned into its tube, so as to expel e gas in a jet suitable for inflammation.

In the case of perphosphuretted hydrogen, the gas burns spontaneously as soon it escapes from the apex. In the case of other inflammable gases, inflammation produced by the flame of a taper.

SECTION IV.

OF CARBON.

Nature presents us with the most beautiful and purest pecimens of this substance. The diamond is pure car- on. When equal weights of charcoal and diamond are everally exposed to the focus of a powerful lens in oxy- en gas, included in different bell glasses, they are both onverted into carbonic acid. In like manner, when dia- iond powder is heated with nitre or iron, the effects are nalogous to those which would arise from charcoal.

Carbon is very abundant in nature, in the various kinds f fossil coal, from anthracite or plumbago, in which it is early pure, to the variety called candle, or cannel coal, hich is replete with bitumen. In bituminous coal there much hydrogen. Carbon pervades vegetable and ani- ial matter as an essential element. It is, especially, a onstituent of the fibres of wood.

Until of late, plumbago was considered as a chemical compound of iron with carbon. Berzelius alleges it to be carbon mingled, but not combined, with iron and other impurities.

I ascertained that anthracite, when completely burned in oxygen gas, produced no diminution of volume, the products being water and carbonic acid. I infer, therefore, that the combustible portion of this coal consists almost solely of carbon, united with hydrogen and oxygen in the proportion for forming water.

Plumbago is sometimes found in the form of hexagonal crystals.

Preparation.—In the laboratory, charcoal is obtained, sufficiently pure, by heating wood intensely in close vessels. In the large way, it is procured by igniting large quantities of wood, so covered with earth, that the access of air may be at first controlled and afterwards prevented.

Coke is obtained from bituminous coal, by a process analogous to that employed for obtaining vegetable charcoal, which it resembles in chemical, though not in mechanical properties.

Properties.—Carbon is inodorous, insipid, and usually black. Charcoal of wood is one of the best radiators, and worst conductors of heat. There is reason for believing this peculiarity to result from its excessive porosity; as in the form of anthracite, carbon conducts heat better, and probably radiates it worse. Charcoal is highly susceptible of galvanic ignition.

Next to the metals, charcoal is the best conductor of electricity. It appears, from the experiments of Professor Silliman, that charcoal, when exposed to the influence of a powerful Voltaic series, undergoes fusion and volatilization, so as to be transferred from the positive to the negative pole, on which it forms a projection.

Charcoal, when intensely ignited without access of air, becomes denser, harder, and a good conductor of heat. Substituting animal products for those of vegetation, in the usual process of carbonization, *animal charcoal* is obtained. It does not, like the coal of vegetable substances, retain the form of the bodies from which it may be procured, and is replete with cavities, created by the escape of the gaseous elements associated with it in the organic state. It has a grayish-black colour, and a [illegible] y resembling that of plumbago.

'arbon is precipitated in various forms from coal gas; ›ng others, in that of long brittle filaments, associated ufts, resembling locks of hair. The specific gravity of bon, in the state of diamond, or in that of common rcoal, when examined in the pulverulent form, so that result shall not be affected by the numerous cavities ting in it when in mass, is about 3.5. The apparent tness of charcoal is caused by its porosity. The spe- : gravity of anthracite does not exceed 1.6; that of nbago is 2.32; yet they are both much more compact a charcoal, and, in proportion to the space occupied them in mass, obviously much heavier.

'arbon, under some circumstances, appears to have a ıscendent affinity for oxygen. In its ordinary state equires a temperature above redness, in order to exhi- this affinity—in other words, to burn. In proportion t becomes denser and more pure, we find it more dif- lt to ignite.

'hus the susceptibility of ignition increases from the nond to tinder in the following order:—Diamond, nbago, anthracite, coke, charcoal of hard wood, char- l of soft wood, tinder.

n some forms, and when mixed with certain metals, ı or antimony for instance, as when obtained by car- izing Prussian blue, or tartrate of ammonia and anti- ıy, it takes fire spontaneously at ordinary tempera- es.

ıccording to Despretz, carbon, during its combustion, lves sufficient caloric to melt one hundred and five es its weight of ice. It is not to be inferred that this rue of carbon in all its forms.

Berzelius alleges that the same degree of heating power ıot possessed by every kind of charcoal; some of its ns, according to him, producing much more heat in ning than others. This I should not believe without clusive evidence.

the Decolorizing and Disinfecting Power of Charcoal.

'arbon, as procured from organic products, especially nal matter, displays a great power to combine with precipitate colouring matters. Hence it is exte ely used in the refining of sugar, and generally in cl mical processes, in which the objects of research are entangled with colouring matter. This power is not inherent in elementary carbon, but appears to be due to its previous associations, or to some peculiarity of arrangement, derived from the process of carbonization.

Animal charcoal is much more efficacious than that derived from vegetables. The carbonaceous mass, obtained by igniting blood with carbonate of potash, appears to have the greatest efficacy. That the presence of an alkali during the ignition contributes to the effect, seems to justify the conjecture that cyanogen, the generation of which, in combination with the alkali, is a necessary concomitant, has some agency in the process. Charcoal is a powerful antiseptic, operating efficiently in preserving water or meat from putridity. Moreover, water, rendered extremely foul, as that from the public sewers, may be purified by filtration through pulverized charcoal. In fact, filters are now extensively manufactured, in which charcoal is the most efficient and only chemical agent employed. The gravel, sand, and sponge, usually associated with it, act mechanically.

Of the Power of Charcoal and other Substances to absorb Aëriform Fluids.

Charcoal, which has in a state of ignition been submerged in mercury, on being introduced into gaseous substances, condenses into its pores a large quantity of the surrounding aëriform matter, whatever it may be. The quantity condensed varies with the gas, from 90 times the bulk of the charcoal, as in the case of ammonia, to 1.75 times its bulk, as in the case of hydrogen. During their absorption, the gases give out heat, and the more in proportion to the rapidity with which the condensation is effected; and if, on the other hand, by exposure within an exhausted receiver, the gas be evolved, cold is produced. Charcoal, thus deprived of gas, reabsorbs any gas exposed to it, as greedily as if recently ignited.

This faculty of absorbing gaseous substances, is impaired by humidity, which charcoal is prone to absorb in the form of vapour, afterwards condensing it into the state of water. Water partially displaces the gases previously absorbed.

The aëriform fluids, absorbed by charcoal, are expelled by heat unchanged, with the exception of sulphuretted hydrogen and oxygen. The former deposites sulphur, and the latter is gradually converted into carbonic acid. The absorption of this last mentioned principle continues for some time, but, in quantity, has not been found to exceed 14 times the volume of the carbon. In a rarefied medium, charcoal absorbs less in weight, but more in volume; so that the increased resistance of the gas, arising from a diminution of pressure, counteracts, to a certain extent, the power of the coal to condense into its pores a certain weight. The power of absorption varies in a degree with the number and minuteness of the pores existing in the charcoal; of course, it varies with the wood by which it is yielded. Charcoal of box-wood is pre-eminent in absorbing power; that furnished by woods of a lighter kind is very inferior in this power. Plumbago and anthracite have no capacity, even after ignition, to absorb gases.

In the property of absorbing aëriform fluids, charcoal is not singular. De Saussure ascertained that different porous minerals, and many kinds of wood, also silken and woollen stuffs, absorb many times their volume of gas.

When porous bodies are placed in a mixed atmosphere of various gases, they are absorbed in proportion to their reciprocal attractions, and that exercised by the pores of the substances employed.

A mixture of oxygen with hydrogen or carbonic acid, is more copiously absorbed than either when alone; yet by heat or exhaustion they are liberated without diminution. Nevertheless, sulphuretted hydrogen and oxygen, when acted upon by charcoal, produce water, sulphur being deposited.

The absorption of moisture by charcoal and other porous bodies has long been noticed. On this account, it is difficult to weigh such bodies without an increase of their weight, even when they are placed in the scale while red-hot. Those aëriform fluids are absorbed to the greatest extent, which are capable of assuming the liquid state.

These facts explain the augmentation in weight received by charcoal exposed to the air, which amounts to between ten and twenty per cent.

I have devoted more space to this subject, because it illustrates a property which otherwise might not be sufficiently considered. It forms a peculiar instance of mechanico-chemical agency, if I may be allowed to use a new word to express the idea. Without the porous or cellular structure which it possesses in the form of charcoal, carbon is not endowed with either disinfecting, absorbing, or colour-removing powers; and yet it is evident that the carbon acts in charcoal by a species of chemical affinity, unaided by which the cellular structure would be inefficient in the processes under consideration. As respects the transmission of contagious or infectious effluvia, the absorbing power of porous bodies merits attention.

I believe that the carbonaceous matter, evolved during the burning of sugar, actually neutralizes those fetid emanations which it is employed to correct in the chambers of the sick.

COMPOUNDS OF CARBON WITH OXYGEN.

One atom or one volume of carbon, equivalent 6,	with one atom or half a volume of oxygen, equivalent 8, forms one atom or one volume of *carbonic oxide*, equivalent 14.
	with two atoms or one volume of oxygen, equivalent 16, forms one atom or one volume of *carbonic acid*, equivalent 22.

Two atoms or volumes of carbon, equivalent 12, with three atoms or one and a half volumes of oxygen, equivalent 24, form one atom of *oxalic acid*, equivalent 36.

Two other compounds of carbon with oxygen are alleged to exist; one called *mellitic*, the other *croconic acid.* The former contains four atoms of carbon to three of oxygen; the latter five of carbon to four of oxygen.

Of Carbonic Oxide.

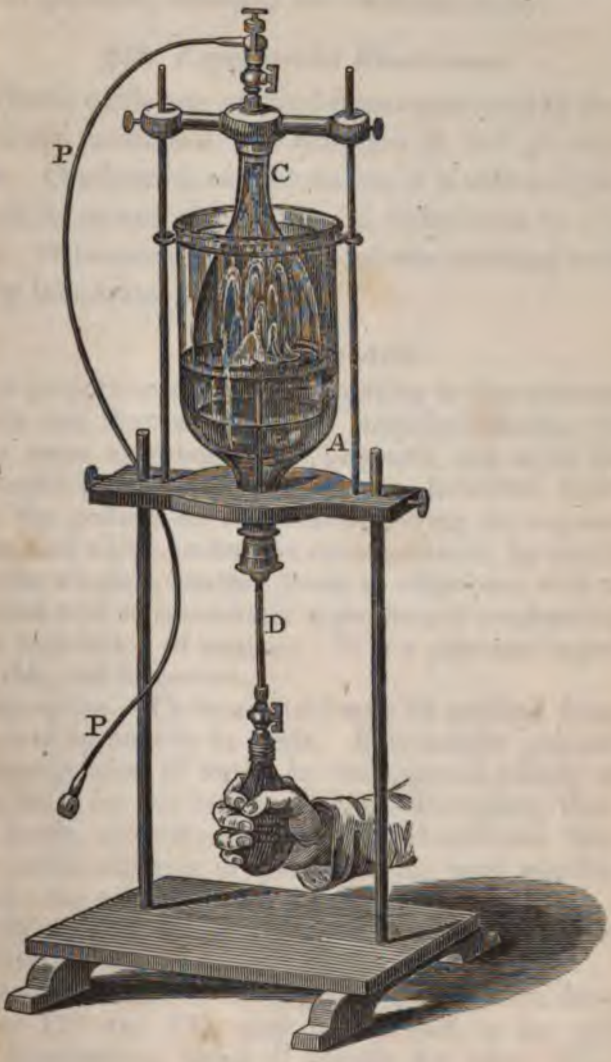
Preparation.—This compound is produced by the combustion of carbon with an inadequate supply of oxygen; or when bodies containing carbonic acid are heated with certain substances having an affinity for oxygen. Thus it may be procured by heating carbonate of lime with iron filings. The best process, however, for obtaining carbonic oxide in a state of purity, is to heat five parts of concentrated sulphuric acid with one of oxalic acid; which, being deprived by the sulphuric acid of the water which is essential to its existence, is resolved into carbonic oxide and carbonic acid. The latter gas may be removed by lime-water, leaving the carbonic oxide in a state of purity.

227. *Apparatus for separating Carbonic Acid from Carbonic Oxide, by Means of Lime-water.*

This apparatus is represented by the opposite engraving. Lime water being introduced in sufficient quantity into the inverted bell glass, another smaller bell glass, C, is supported within it as represented in the engraving. Both of the bells have perforated necks. The inverted bell is furnished with a brass cap having a stuffing box attached to it, through which the tube, D, of copper, slides air-tight. About the lower end of this tube, the neck of a gum elastic bag is tied; so that the cavity of the bag may communicate with that of the tube. The neck of the other bell is furnished with a cap and cock, surmounted by a gallows screw, by means of which the leaden pipe, P P, with a brass knob at the end suitably perforated, may be fastened to it, or removed at any moment. Suppose this pipe, by aid of another brass knob at the other extremity, to be attached to the perforated neck of a very tall bell glass filled with water upon a shelf of the pneumatic cistern: on opening a communication between the bells, the water will subside in the tall bell glass over the cistern, and the air of the bell glass, C, being drawn into it, the lime-water will rise into and occupy the whole of the space within the latter. As soon as this is effected, the cocks must be closed, and the tall bell glass replaced by a small one filled with water, and furnished with a gallows screw and cock. This bell being attached to the knob of the lead pipe, to which the tall bell had been fastened before, the apparatus is ready for use. I have employed it in the new process for obtaining carbonic oxide from oxalic acid, by distillation with sulphuric acid in a glass retort. The gaseous product consists of equal volumes of carbonic oxide and carbonic acid, which, being received into a bell glass, communicating, as above described, by a pipe with the bell glass, C, may be transferred into the latter, through the pipe, by opening the cocks. As the gaseous mixture enters the bell, C, the lime-water subsides. As soon as a sufficient quantity of the gas has entered, the gaseous mixture, by means of the gum elastic bag and the hand, may be subjected to repeated jets of lime-water, and thus depurated of all the carbonic acid. By raising the liquid in the outer bell, A, the purified carbonic oxide may be propelled through the cock and lead pipe, into any vessel to which it may be desirable to have it transferred.

Properties of Carbonic Oxide.—Carbonic oxide is a colourless, insipid gas, indecomposable by heat or electricity, and incapable of reddening litmus. Its specific gra-

pparatus for separating Carbonic Acid from Carbonic Oxide, by Means of Lime-water.



vity is 0.9727. It does not support combustion and is destructive to life. It burns with a feeble blue flame, and, combining with oxygen, is converted into carbonic acid. By platinum sponge, a mixture of oxygen and carbonic oxide is gradually changed into carbonic acid.

228. *Experimental Illustrations.*

Carbonic oxide gas, evolved from oxalic acid by the process above mentioned, and collected in bell glasses over water. Combustion and detonation of it with oxygen gas, effected by means of a sliding rod eudiometer, or volumescope. Subsequent absorption of the resulting carbonic acid by lime-water, shown.

Of Carbonic Acid.

The proportion of this gas, existing in the atmosphere, is much less than was formerly supposed; being, according to some experiments of Thenard, not more than a thousandth part. It is this portion, however, that produces the pellicle on lime-water, during its exposure to the air, and which, under like circumstances, by combining with the alkalies, enables them to effervesce with acids. Carbonic acid is incessantly a product of combustion and of the respiration of animals. It is a principal ingredient in marble and limestone.

Preparation.—Carbonic acid may be evolved from any carbonate by heat or by acids. It is usually procured for the impregnation of water, by the superior affinity of sulphuric acid for the lime in marble. Excepting that it is more costly, chlorohydric acid is preferable for this purpose; as the chloride of calcium, being very soluble, does not, like the sulphate, clog the vessels.

Carbonic acid is evolved copiously during the vinous fermentation.

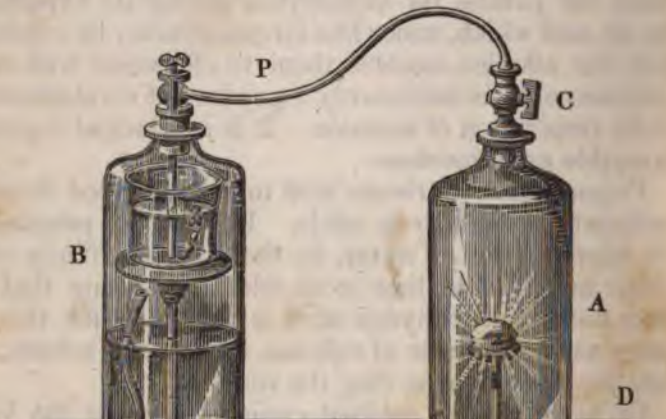
The process and the self-regulating reservoirs, described articles 172 and 173, may be resorted to for carbonic acid, substituting lumps of marble for zinc. The best materials for the evolution of this gas, agreeably to my experience, are chlorohydric acid and calcareous stalactites.

Carbonic acid might be procured at a trifling cost, by drawing, by the aid of a suction pump, the effluvium of burning charcoal through water to deprive it of dust, and then forcing it into the cavities in which its presence may be desirable.

This process for the production and employment of carbonic acid, generated by the combustion of charcoal, is illustrated in the small way by the following engraving and description.

229. *Combustion of Charcoal or other Combustibles in Oxygen Gas.*

The following cut represents an apparatus which I have contrived for exhibiting the combustion of charcoal, or other combustibles, in oxygen gas. Two large glass bells, A, B, each furnished with a tubulure at the apex, are associated by means of the pipe, P, which, in one of the bells, B, communicates with a tube, extending about five inches within the bell, below its neck, so as to reach into some lime-water, or an infusion of litmus, contained in a glass vessel, resting on a stand, as represented in the figure. The wooden stand which holds the glass vessel, and the iron stand which supports the coal in the bell, A, must be previously placed on the shelf of the pneumatic cistern, as represented in the cut; so that A, when including the coal, may be over the mouth of the cock, D, which communicates with one of the gas holders, situated under the shelves of the pneumatic cistern, which, for this experiment, should be filled with oxygen.



Into the bell glass in which the glass is placed, a pipe from the suction pump of the hydrostatic blowpipe is made to enter, and reach nearly to the stand. The apparatus having been prepared thus far, the bells must be lifted so as to permit a live coal to be put upon the iron stand, as represented in the figure. As soon as they are restored to their previous situations, the suction pump must be put into operation, and the cock, D, of the gas holder, containing the oxygen, opened; so as to allow a cur- [illegible] he gas to have access to the coal, by replacing the air, which is withdrawn by the pump through the pipes, P and E. The coal burns splendidly; and as the oxygen becomes saturated, it is drawn off by the suction pump, being made, in its way from A to B, to pass through the liquid in the vessel, into which descends the tube proceeding from A. If the liquid be water tinged with litmus, it will become red by the action of the carbonic acid: if it be lime-water, a copious milky precipitate will appear.

Properties of Carbonic Acid.—It is a colourless gas, with a pungent smell and an acid taste. At the temperature of 32°, and under a pressure of forty atmospheres, it condenses into a colourless liquid. Water takes up its own bulk of this gas, whatever may be its density. It combines with earths, alkalies, and metallic oxides, forming with lime, baryta, strontia, magnesia, and oxide of lead, compounds which are insoluble. Hence it precipitates lime-water, barytic-water, and solution of acetate of lead. Litmus is reddened by this acid. It destroys life and extinguishes flame, but is not insalubrious to breathe when much diluted with air.

Carbonic acid is very antiseptic. When concentrated in water it is grateful to the stomach. Potassium burns in this gas, absorbing oxygen and precipitating carbon. Plants probably absorb it, retain its carbon, and give out its oxygen. The respiration of animals tends to compensate this change, by carbonizing the oxygen of the air.

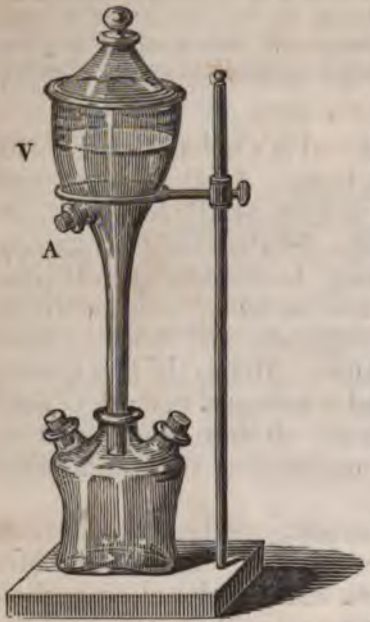
Carbonic acid is heavier than atmospheric air, its specific gravity being 1.5239.

230. *Experimental Illustrations.*

Evolution of the gas, shown; also its property of extinguishing a candle. That it differs from nitrogen, made evident by means of lime-water. Litmus, reddened by carbonated water, and restored to its original colour by boiling.

Analysis of mixtures containing the gas, by means of the sliding rod eudiometer and lime-water.

231. *Apparatus for showing some of the distinguishing Properties of Carbonic Acid Gas.*



Having introduced into the three-necked bottle, represented in the adjoining figure, one or two ounces of carbonate of ammonia, add about half as much nitroso-nitric acid. An active effervescence will ensue, arising from the expulsion of the carbonic acid from the ammonia, by the stronger affinity of the nitric acid. At the same time, sufficient fume will be generated to make it evident how far the vessels are occupied by the gas, to the exclusion of atmospheric air. By these means the movements of the carbonic acid gas will be recognised as ascending to the upper vessel, which it will fill, and finally overflow through the crevice between the brim and cover.

The cover being removed, a lighted candle will cease to burn, when lowered into the fume indicating the space occupied by the gas. This space will comprise the whole cavity of the vessel, so long as the aperture, A, is closed; but, on removing the cork from this aperture, the gas will flow out, and the stream, marked by the accompanying fume, will be seen descending towards the table, and will extinguish the flame of a candle if made to encounter it; or, it may be received into a mug, so as to arrest the combustion of a taper introduced into it, or upon which the contents of the mug may be poured.

Under these circumstances, a taper will burn anywhere within the vessel, V, if it be not below the aperture, A, above which the gas is not now seen to extend itself. But if one of the orifices of the bottle be opened, the carbonic acid will be found entirely to desert the upper vessel.

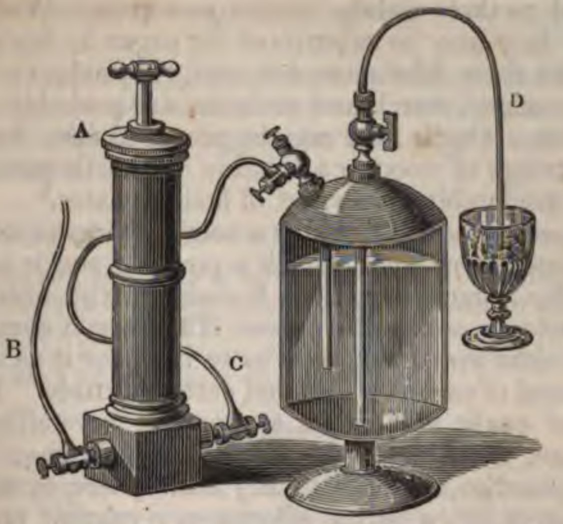
It will thus be made evident that this gas, from its greater specific gravity, has, in the atmosphere, some of the habitudes of liquids; while its incapacity to support combustion will be demonstrated.

The specific gravity of carbonic acid being rather more than one-half greater than that of atmospheric air, it does not speedily leave any cavity in which it may be introduced. It is on this account that persons often perish on entering wells.

232. *Impregnation of Water with Carbonic Acid.*

The process by which water is impregnated with carbonic acid, may be easily understood from the following engraving.

A condenser, A, is fastened at bottom into a block of brass, which is furnished with a conical brass screw, by means of which it is easily attached firmly to the floor. In this brass block are cavities for the two valves, one opening inwards from the pipe, B, the other outwards towards



the pipe, C. The pipe, B, communicates with a self-regulating reservoir of carbonic acid.

The gas which the condenser draws in from the reservoir, is forced through the other pipe into a strong copper vessel, in which the water is situated, and which is represented in the figure, as if the front part were removed, in order to expose the inside to inspection.

If due care be taken to expel all the air in the vessel before the impregnation is commenced, the water will take up as many times its bulk of gas, as the pressure employed exceeds that of the atmosphere.

When duly saturated, the water may be withdrawn at pleasure by means of the syphon, D, of which one leg descends from the vertex of the vessel to the bottom, while the other is conveniently situated for filling a goblet.

Of Oxalic Acid.

Latterly oxalic acid, long known as a product of vegetation, has been found to belong to the compounds of carbon with oxygen; and still more lately mellitic and croconic acid have been added to this class. Yet when the necessity of water to the existence of these acids is taken into view, it appears to me questionable whether they may not be considered as acids with a compound radical, consisting of hydrogen and carbon.

Preparation.—Oxalic acid may be obtained from the common sorrel, *Rumex acetosa*, or from the wood sorrel, *Oxalis acetosella*, from which it derives its name. In these plants it exists in the state of binoxalate of potash. It may also be procured by the reaction of one part of sugar with six of nitric acid. The weight of the acid obtained is equal to three-eighths of the materials. Wood, glue, silk, or hair may be substituted for sugar in this process; but when these substances are used, the product is impure. Next to sugar, starch and molasses are probably the best materials. Oxalic acid may be procured also, by digesting shavings of wood in a solution of caustic potash, at a heat considerably above that of boiling water.*

Properties.—Oxalic acid is a solid, having an extremely sour taste. One grain in half a pint of water is sufficient to redden litmus distinctly. It cannot exist uncombined with water or some other base. The atomic composition of this acid would authorize us to consider it as a binary compound of carbonic acid and carbonic oxide. In every atom of oxalic acid in its appropriate crystalline form, there are three atoms of water. When these crystals are exposed to an unusually dry atmosphere, or to a temperature of 80°, a partial efflorescence ensues; and if the heat be raised to 212°, they part with two atoms of water, which they recover on exposure to the air after cooling. When heated to 300°, the acid is decomposed.

Oxalic acid is an energetic poison. The best antidotes for it are magnesia, or the calcareous carbonates in the pulverulent form, especially chalk. When oxalic acid meets with either of these bases, an insoluble and inert oxalate is formed.

With chlorohydric acid, oxalic acid forms a crystalline compound called *chloroxalic acid*, which may be obtained by exposing acetic acid to the rays of the sun in a vessel filled with chlorine. Oxalic acid is soluble in water and alcohol.

Of Mellitic Acid.

Mellitic acid is obtained in crystals from a rare mineral called the honey-stone, which is a mellitate of alumina. It is soluble in water and alcohol, and has a sour taste.

Of Croconic Acid.

Croconic acid may be procured in yellow crystals, from the croconate of potash, which is generated in the process for obtaining potassium by means of charcoal.

---

* This process was suggested by Gay-Lussac. See Quarterly Journal, N. S. 413.

t is inodorous, has an acid and astringent taste, and redens litmus.

The oxalic, mellitic, and croconic acids resemble vegeable acids so much, that they are usually classed with hem; although, excepting oxalic acid, they are not vegeable products.

OMPOUNDS OF CARBON WITH OXYGEN AND CHLORINE.

There are two compounds of carbon with oxygen and chlorine. To ne of these, which has been recently discovered, the name of *chloral* has een given; to the other, that of *chlorocarbonic* or *chloroxycarbonic acid.* he latter name is preferable; as the other would convey the idea of an cid made solely by the union of chlorine with carbon.

Of Chloral.

When chlorine is passed through alcohol, which consists of hydrogen, xygen, and carbon, one portion combines with hydrogen, forming chloroydric acid, while another combines with oxygen and carbon, forming hloral.

Chloral is described as a colourless transparent liquid with a pungent dour. Its specific gravity is 1.502. It boils at 201°, and may be dislled unchanged. With water it forms a white crystalline mass, appaently a hydrate.

Chloral consists of nine atoms of carbon, four of oxygen, and six of hlorine.

Of Chloroxycarbonic Acid.

When one volume of dry chlorine and one volume of carbonic oxide as are mingled, and exposed to the solar rays, they combine, and conense into one volume of a colourless acid gas, to which the name of hloroxycarbonic acid has been given. It is exceedingly offensive to the yes and to the organs of respiration. It reddens litmus paper, and with mmonia forms a white salt. By contact with water a reciprocal decomosition ensues, and chlorohydric and carbonic acids are produced. It onsists of one atom of chlorine, and one atom of carbonic oxide.

Of the Chlorides of Carbon.

Chlorine forms four compounds with carbon. The *dichloride* is a white crystalline inflammable solid, having a peculiar odour, resembling that of spermaceti. At 250° it sublimes in crystals. It is fusible by heat, and boils at a temperature between 350° and 450°. The dichloride consists of one atom of chlorine and two of carbon.

The *protochloride* is obtained by passing the sesquichloride in vapour through a red-hot porcelain tube. The sesquichloride is decomposed into the protochloride and chlorine. The protochloride is a transparent colourless liquid, with a specific gravity of 1.4875. It is composed of one atom of chlorine and one of carbon.

When the liquid, produced by the union of chlorine with olefiant gas, usually called chloric ether,* is exposed to the sun, in contact with a sufficient quantity of chlorine, the ***sesquichloride of carbon*** is produced. It is a colourless, transparent, friable, crystalline body, nearly tasteless, and resembling camphor in smell. While exposed to the flame of a spirit lamp, it burns with a red flame, but the combustion ceases as soon as the lamp is removed. It melts at 320°, and at 360° is converted into vapour which may be condensed without decomposition. It is nearly twice as heavy as water. The sesquichloride of carbon consists of three atoms of chlorine and two atoms of carbon.

---

* See page 291.

All the above described chlorides are insoluble in water, acids, and alkalies, but are soluble in oils, alcohol, and ether. When chloral is boiled in a solution of potash, a decomposition ensues, and a chloride of carbon is evolved in vapour, and may be condensed in a receiver. This chloride is a colourless transparent liquid, with an odour similar to that of chloric ether. Its specific gravity is 1.48. This chloride consists of five atoms of chlorine and four of carbon.

Of Bromide of Carbon.

When bromine is brought in contact with half its weight of periodide of carbon, heat is evolved, a decomposition ensues, and bromides of iodine and carbon are formed. The bromide of carbon is a volatile, colourless liquid, of a sweet taste, and an ethereal odour.

Of the Iodides of Carbon.

The ***protiodide*** of carbon is a liquid, in properties strongly resembling the bromide of carbon. The ***periodide*** appears under the form of yellow crystalline scales, which have a sweet taste, a strong aromatic smell resembling that of saffron, and a specific gravity higher than that of water.

Of Sulphocarbonic Acid, or Bisulphide of Carbon.

The bisulphide of carbon is obtained by passing the vapour of sulphur over charcoal heated to incandescence in a porcelain tube. It is a transparent, colourless, volatile liquid, possessing an acrid taste, and a peculiar nauseous smell. Its specific gravity is 1.272. It boils at 105°, and does not freeze at —60°. At a temperature a little above the boiling point of mercury, it inflames. When the bulb of a spirit thermometer, wrapped in lint imbued with this liquid, is placed within a receiver, and the air withdrawn, the temperature falls to —82°.

This compound unites with almost all the sulpho-bases, forming with them sulpho-salts, and is as well entitled to be treated as an acid, as the analogous compound formed by sulphur with hydrogen.

Dr. Thomson supposes that the solid mass, obtained by washing the nitre out of gunpowder, is probably a solid sulphide of carbon.

Of Xanthohydric Acid and Xanthogen.

Mr. Zeise discovered that, when the bisulphide of carbon is agitated with a solution of pure potash in alcohol, cooled to 32°, acicular crystals are deposited. These crystals are composed of potash united to an acid, to which Mr. Zeise has given the name of hydroxanthic. According to the nomenclature which I have adopted, it should be called xanthohydric acid. In order to procure this acid, the xanthohydrate of potash, obtained by the process above mentioned, is to be exposed to the action of sulphu- d, which, from its superior affinity, unites with the potash, and libeates xanthohydric acid. This acid is an oleaginous, colourless, inflammable liquid, heavier than water, of which the taste is at first sour, subseuently astringent and bitter, and the odour strong and peculiar. Litmus s reddened when exposed to its action. Mr. Zeise supposes this acid to onsist of hydrogen, and a compound of carbon and sulphur, which he alls *xanthogen*, and which in this acid plays the same part as cyanogen n prussic or cyanhydric acid. He supposes that xanthohydric acid, when presented to certain metallic oxides, is resolved into water, and a xanthide f the metal employed.

COMPOUNDS OF CARBON WITH HYDROGEN.

Carbon and hydrogen are in opposite extremes, as respects their susceptibility of the aëriform state. Per se, carbon is probably more difficult of volatilization by heat than any other substance in nature. Hydrogen, on the other hand, as far as our experience goes, is not susceptible of condensation, even into the non-elastic state of luidity. There is, however, a powerful affinity between these substances; and hence, when a compound which contains them is subjected to heat, they are made to combine in various proportions, according to the intensity of the ignition, and the influence exercised by the nitrogen, or oxygen, which may have been associated with them.

In general, the compounds of carbon with hydrogen are distinguished by inflammability. In the gaseous state they constitute, when ignited, the flame of candles, lamps, gas lights, and culinary fires. They are incapable of supporting life, but are not actively noxious to the organs of respiration, when diluted with the air.

The gaseous compounds of carbon with hydrogen are obtained by the destructive distillation of bituminous coal, wood, oil, tar, and other inflammable substances.

The illuminating power of these various forms of gas, seems to be in proportion to the quantity of carbon condensed into a given volume, provided there be oxygen enough to consume it; but, otherwise, the excess of carbon renders the flame smoky. Hence the greater brilliancy of small flames, or those excited by a current of air, as in the Argand lamp.

The same flame which in common air is unpleasantly fuliginous, transferred to oxygen gas, displays a perfect brilliancy.

The known compounds of carbon with hydrogen are numerous and complicated; and yet it is probable
many exist in nature, or may be produced by a

which we are at present unacquainted. We have had occasion to state, page 268, that where bodies have, in the same volume, the same number of atoms of each of their ingredients, and yet differ in their properties, they are said to be *isomeric*, from ισος equal, μερος part. Compounds, in which the constituents are in the same ratio, but in which the resulting volumes exist in different degrees of condensation, are said to be *polymeric* with respect to each other, from πολυς many, μερος part. The last term is applied to a class of the compounds of carbon with hydrogen, in all of which these elements exist in the same ratio of atom for atom; yet from some difference in the mode of aggregation, or, as I believe, in the extent and modes of their association with heat, light, and electricity, their degree of condensation when in the aëriform state, and their properties in other respects are quite different.

We have then two groups of the carburets of hydrogen, in one of which diversity of properties is attended by a corresponding diversity in the ratio of the carbon to the hydrogen; while in the other this ratio is uniform, although the properties and resulting volumes in the aëriform state, differ.

In the first group, there are four compounds.

1. *Light carburetted hydrogen*, or *fire damp*, consisting of two volumes or atoms of hydrogen, with one volume or atom of carbon.

2. The compound, in all the varieties of which there are as many atoms of one element as of the other, and for which Dr. Thomson proposes the name of *carbohydrogen* as a generic appellation.

3. *Bicarburet of hydrogen*, in which six atoms of carbon are united with three of hydrogen.

4. *Naphthaline*, in which ten atoms of carbon are combined with four atoms of hydrogen.

The second group, which is subordinate to the first, being formed in fact by the ramifications of carbohydrogen, comprises, according to Dr. Thomson, several varieties, which he designates and describes as follows:—

1st. *Protocarbohydrogen*, consisting of a volume of carbon and a volume of hydrogen, condensed into one volume. This variety, now called *mytheline*, has been lately iso[illegible]d by Dumas and Peligot, by distilling one part of pyr[illegible]ic spirit, obtained by the distillation of wood, with two parts of chlorohydric acid, and three of sulphuric acid; when an ethereal chlorohydrate of mytheline results. Subjected to a red heat, this ethereal compound is resolved into chlorohydric acid gas, and mytheline in the gaseous form. Pyroxylic spirit is considered as a bihydrate of mytheline, being procured from crude pyroligneous acid by distillation. It bears the same relation to mytheline that alcohol does to etherine.

2d. *Deutocarbohydrogen*, or *olefiant gas*, consisting of two volumes of carbon and two of hydrogen, condensed into one volume.

3d. *Tritocarbohydrogen*, consisting of three volumes of carbon and three of hydrogen, condensed into one volume. This is by Dr. Thomson considered as constituting the gas evolved from oil, which was by Dalton called superolefiant gas.

4th. *Tetartocarbohydrogen*, or *etherine*, consisting of four volumes of carbon, and four volumes of hydrogen, condensed into one volume.

5th. *Hexacarbohydrogen*, containing, according to Thomson, six volumes of each element, condensed into one volume.

Of Light Carburetted Hydrogen, or Fire Damp.

The substance distinguished by these names, has been dignified by a variety of appellations, among which are heavy inflammable air, carburetted hydrogen, and bihydroguret of carbon. Dr. Thomson has, in some instances, used the monosyllable *di* to indicate proportions, the inverse of those indicated by the monosyllable *bi*. Thus, bichloride of carbon would signify two atoms of chlorine and one of carbon, while dichloride conveys the idea of two atoms of carbon and one of chlorine. Consistently, then, I think, Dr. Thomson should have called this gas, a *dicarburet of hydrogen;* as the proportions of its constituents are the inverse of those in the bicarburet. This gas has long been known to miners of bituminous coal, under the name of fire damp, as one of their greatest enemies. It is liberated copiously from cavities in the coal, in which, no doubt, in many instances, it has been pent for ages. It is also evolved from the mud of stagnant waters, and is occasionally emitted from fiss the earth. There is no good mode of forming i
It is a colourless gas, of course irre

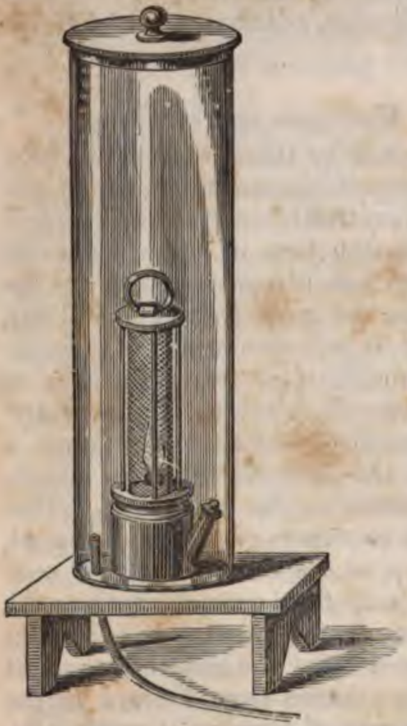
more than a negative influence in destroying life. Its specific gravity is 0.5593.

233. *Of the Safety Lamp.*

In the account above given of dicarburet of hydrogen, it was mentioned that it was in mines a source of injury. When existing in the air beyond a certain proportion, it explodes on coming into contact with the flame of a lamp or candle. Hence, as artificial light is necessary in mines inaccessible to the light of day, the use of candles or lamps, in the ordinary way, has been frequently destructive to the workmen. It had, of course, been the cause of great anxiety to them, and of embarrassment to the proprietors of the mines.

In order to avoid the risk attending the use of lamps or candles in mining, a steel mill had been resorted to, in which the rapid revolution of a steel wheel against a flint, was made to produce a succession of sparks, and of course a feeble light. I believe that the security afforded by this invention was imperfect, and the light insufficient. Explosions have been more frequent in the English mines of late years, probably in consequence of the greater extent and depth to which they are excavated. While under the painful impression made by some recent catastrophes of this nature, in which many miners had been killed or mutilated, Sir H. Davy exerted himself to discover the means of sustaining flame safely within explosive gaseous mixtures. He soon ascertained that his object might be effected by enclosing the flame in a cage of wire gauze, so as to allow of no communication with the surrounding medium, which does not take place through the meshes of the gauze. Owing to the cooling power of the wire, the mixture cannot pass through the meshes in a state of combustion. Of course the inflammation is confined within the wire gauze.

The method in which I illustrate the operation of the safety lamp, may be easily comprehended from the following figure. The lamp is seen within a large glass cylinder upon a stool. The cylinder is closely covered by a lid, which will not permit the passage of air between it and the cylinder, and which is so light as to be easily blown off. Excepting the cage alluded to above, the safety lamp does not differ materially from those which are ordinarily used. The upper surface of the receptacle for the oil, forms the bottom of the cage, which is so closely fitted to it, and so well closed every where, as to allow air to have access to the flame only through the meshes of the wire gauze. The cage is enclosed within three iron rods, surmounted by a cap, to which a ring for holding the lamp is attached, as seen in the figure.



If, while the lamp is burning, as represented in the figure, hydrogen, either pure or carburetted, be allowed, by means of the pipe, to enter the glass cylinder, so as to form with the air in it an explosive mixture, there will nevertheless be no explosion. It will be found that as the quantity of inflammable gas increases, the flame of the lamp enlarges, until it reaches the wire gauze; where it burns more or less actively, accordingly as the supply of atmospheric air is greater or less. It will, under these circumstances, often appear as if the combustion had ceased; but on increasing the proportion of atmospheric air, the flame will gradually contract, and finally settle upon the wick, which will burn as at first when the supply of hydrogen ceases.

If the cage be removed from the lamp, and the experiment repeated in all other respects as at first, an explosion will ensue, as soon as a sufficient quantity of hydrogen is allowed to enter the cylinder.

Of Deutocarbohydrogen, or Olefiant Gas, called also Carburetted Hydrogen, and Hydroguret of Carbon.

This gas received its name in consequence of its being condensed with chlorine into a liquid, having an oleaginous consistency, although otherwise unlike an oil. It was discovered in the year 1796. It may be obtained by passing the vapour of alcohol through a red-hot porcelain tube, or by subjecting a mixture of five parts of sulphuric acid with one of alcohol to heat in a glass retort. It is invisible, and possesses, like other gases, the mechanical properties of atmospheric air. Its specific gravity is 0.9808. When drawn into the lungs it produces asphyxia. It burns with great splendour, and detonates with oxygen with such violence, that without some precautions it is dangerous to analyze it by the usual processes. I have had several eudiometers broken by it, but have latterly avoided that accident, by exploding the mixture in a rarefied state, into which it is easily brought in some of the instruments which I employ.

The analysis may be performed in the volumescope for analyzing the air by means of hydrogen, with a degree of accuracy sufficient for the purpose of illustration. Four volumes of oxygen should be added to one of the gas. The ignition being effected as already described in the case of pure hydrogen, it will be seen that the five volumes are reduced to less than three, and that by the introduction of lime-water, these three may be reduced to one residual volume of oxygen. The reason why the residual gas is less than three volumes, is, that the carbonic acid formed is partially absorbed by the water. As the gas contains in one volume, two volumes of hydrogen, and two of carbon vapour, it will, for the latter, require two volumes, for the former, one volume of oxygen. Of course the hydrogen, and the oxygen which combines with it, will be condensed; so that after the explosion, unless so far as absorbed by the water, two volumes of carbonic acid will remain mingled with the one volume of oxygen in excess.

In the Appendix I shall give an account of some instruments, by which this and other inflammable compounds of carbon may be analyzed with accuracy.

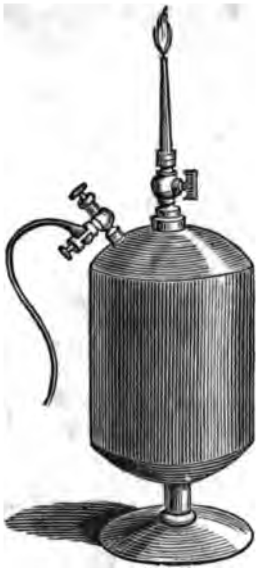
234. *Experimental Illustrations.*

Cork, cotton-seed, caoutchouc, and nuts, introduced in small quantities into a gun-barrel, of which the butt-end has been heated to a bright red heat. Brilliant jet of flame proceeds from the touch-hole. Inflammation of the gas extricated by distillation from oil or bituminous coal: also of olefiant gas. Olefiant gas, mixed with oxygen gas, and exploded in a sliding rod eudiometer. Residue renders lime-water milky.

235. *Of Gas Lighting.*

The gaseous compounds of carbon and hydrogen have been much applied to the purpose of illumination.

The gas, for this purpose, is obtained by the destructive distillation of bituminous coal, oil, or resinous substances, and is received in gasometers, whence it is distributed through pipes to the burners. See page 159, article 159.



One of the greatest obstacles to the general employment of gas lights as a substitute for candles and lamps, is the necessity of pipes leading from gasometers to all situations where the light is wanted. The condensation of the gas into strong metallic receivers, has been resorted to in order to obviate this difficulty. This process may be illustrated by means of the apparatus described for the impregnation of water with carbonic acid, being modified as represented in the adjoining cut.

It is only necessary to exchange the communication with the self-regulating reservoir of carbonic acid gas, for a similar communication with a reservoir of olefiant gas; and the copper vessel being first exhausted of air, to condense the gas into it. The syphon used for the efflux of the impregnated water, is replaced by a cock and tube, the latter terminating in a capillary perforation. Through this, the gas may be allowed to escape in a proper quantity to produce a gas light when inflamed. It has, however, always appeared to me, that the expense of condensing the gas, and of procuring and transporting the receivers, would render this method of affording light disadvantageous.

Latterly, the loss of gaseous matter, by condensation, has been found so great as to render the process unprofitable.

Of some Varieties of Carbohydrogen, and of the Bicarburet of Hydrogen.

Tetartocarbohydrogen, hexacarbohydrogen, and bicarburet of hydro- were all obtained by Mr. Faraday from the liquid which is deposited from oil gas, when condensed into vessels under great pressure for the purposes of illumination.

On subjecting the matter, deposited as above described, to a very gentle heat, *tetartocarbohydrogen* or *etherine* is separated in the form of a transparent colourless inflammable gas, with a specific gravity of 1.9444. When cooled to zero, it condenses into a transparent colourless liquid of the specific gravity of 0.627, being the lightest liquid known.

When the liquid remaining after the extrication of the tetartocarbohydrogen is heated, vapour is evolved, and the boiling point continually rises until the temperature of 176° is attained. Between this temperature and 190°, a large portion distils in the form of a liquid. When this liquid is cooled to zero, it separates into two compounds, one of which becomes solid, while the other continues liquid. The liquid is the compound which Dr. Thomson calls *hexacarbohydrogen*, though its composition does not appear to have been well ascertained. It is inflammable, soluble in alcohol, and boils at 176°. The solid compound is the *bicarburet of hydrogen*. It is at ordinary temperatures a colourless, transparent, volatile liquid, which boils at 186°, and has a specific gravity of 0.85. At 32° it crystallizes, and, when cooled to zero, acquires a consistency like that of loaf sugar.

Of Naphthaline.

Naphthaline is obtained by subjecting to distillation the tar which is formed during the decomposition of bituminous coal. The first products are ammonia, water, and the liquid called coal naphtha; but towards the close of the process naphthaline is obtained.

Naphthaline is a white crystalline substance, with an aromatic smell, and a pungent disagreeable taste.

There are other compounds of carbon and hydrogen,—native naphtha for instance, and oil of turpentine; also many of the essential oils derived from vegetables. Of some of these I shall hereafter treat; to notice them all would be inconsistent with the limits prescribed to this work.

Of the Compounds formed by Carbon with Chlorine and Hydrogen.

It has already been stated that olefiant gas received its name in consequence of its being condensible with chlorine into a liquid of an oleaginous consistency. To this liquid the name of chloric ether has been improperly given, as it indicates a dependency on chloric acid for its constitution or generation, contrary to the fact. As it consists of two atoms of chlorine and one of etherine, a more appropriate name would be *bichlorine ether*.

Bichlorine ether is limpid and colourless like water, has an agreeable smell, and a peculiar sweetish agreeable taste.

Chlorine combines with several other of the polymeric varieties of carbohydrogen, forming with them compounds of different properties. It also produces two compounds by combining with the bicarburet of hydrogen; one solid, the other liquid.

COMPOUND OF CARBON WITH NITROGEN.

Of Bicarburet of Nitrogen, or Cyanogen.

Cyanogen ranks next to iodine among electro-negative bodies. It is included among the halogen bodies of Berzelius, and in the basacigen class by me. Being a compound, I have deferred treating of it until now.

Preparation.—Cyanogen is obtained by subjecting pure and dry bicyanide of mercury to a low red heat in a porcelain or coated glass retort or tube, and receiving the product over mercury.

Properties.—Cyanogen is a colourless, transparent, irrespirable gas, which painfully affects the nose and eyes, and has a strong and peculiar odour. Under a pressure of four atmospheres, it becomes a colourless liquid, lighter than water. It may likewise be liquefied, or even solidified by cold. It is characterized by burning with a beautiful violet flame.

It is decomposed by the electric spark, or by an incandescent iron into its constituents, carbon and nitrogen. Alcohol dissolves twenty-three times, and water four and a half times its volume of cyanogen. In the course of a few days the solutions become discoloured, and a brown matter is deposited. The deposition from alcohol has been found to contain carbon and nitrogen. After obtaining cyanogen from the bicyanide of mercury, a black residuum is found in the retort, which has been conceived to consist of carbon with a less proportion of nitrogen than exists in cyanogen; but of late, this residuum, and the deposition from alcohol, have been supposed to be isomeric with cyanogen.

When ignited with two volumes of oxygen, a volume of cyanogen is converted into two volumes of carbonic acid and one of nitrogen, without condensation. Of course, as each volume of carbonic acid requires a volume of carbon vapour, there must exist two such volumes in one of cyanogen. Hence, as in the case of carbon and nitrogen each volume represents an atom, cyanogen consists of

two atoms of carbon = 12
and one of nitrogen = 14
—
and its equivalent is 26

Of a new Compound of Carbon with Nitrogen.

Mr. Liebig alleges that he has discovered a new compound of carbon and nitrogen, which, if his statements are correct, will probably be found to belong to the basacigen class. It is composed of three atoms of carbon and five of nitrogen. It was obtained in the pulverulent form, is insoluble in water, and decomposable at a red heat into cyanogen and nitrogen.

Of the Nomenclature of the Compounds of Cyanogen.

When Prussian blue is digested with a solution of potash, and the resulting solution is filtered while hot, yellow crystals are deposited by refrigeration, called ferroprussiate or ferrocyanate of potash, under the idea that they consist of an acid composed of iron, cyanogen, and hydrogen, in union with the oxide of potassium. Berzelius considers these yellow crystals as a double salt, formed by a "*cyanure*" of iron, and a "*cyanure*" of potassium. The name of this double salt, agreeably to his nomenclature, is "*cyanure ferroso-potassique.*" He alleges the existence of another compound containing the same elements, in which the proportion of cyanogen to that in the first mentioned compound, is as 1½ to 1, and for which his name is "*cyanure ferrico-potassique.*"

The existence of these combinations constitutes one instance among many, in which, according to Berzelius, two compounds, each having the same halogen body as an ingredient, form by their union a double salt.

Agreeably to his system, we have double "*chlorures, bromures, fluorures,*" and "*iodures,*" as well as double "*cyanures.*"

Some years ago, Bonsdorf, a skilful and sagacious German chemist, assailed this classification of Berzelius, by showing that some of the "*chlorures*" of the double salts exercised an alkaline, others an acid reaction; and that consequently the double "*chlorures,*" so called by Berzelius, were really simple salts, in which one chlorure acted the part of an acid, the other of a base. Merely on contemplating the facts of the case, as stated by Berzelius, without having any knowledge of Bonsdorf's experiments and conclusions, the conviction arose in my mind that the double haloid salts, of that great chemist, should be considered as compounded of acids and bases. I cannot conceive wherefore Bonsdorf thought it necessary to show that there was, in one of the ingredients of a double "chlorure," an acid, in the other, an alkaline reaction, in order to prove the former to act as an acid, and the latter as a base. It appears to me, as I have stated more fully in my letter on the Berzelian nomenclature, that, excepting in the case of the alkalies and alkaline earths, these properties have not been deemed essential to oxacids and oxibases, and that of course they ought not to be required in acids or bases formed by any other of the basacigen class. Agreeably to the definitions of acids and bases, given at page 252, and in my letter above mentioned, the "*cyanure*" of iron being electronegative as contrasted with the "*cyanure*" of potassium, the one must be deemed a cyanobase, the other a cyanacid.

Berzelius extends to all oxides a method of distinguishing their degrees of oxidation, which has been adopted by other chemists, only in the case of the oxides of nitrogen or that of carbon, although generally employed by them in respect to the oxacids. Thus in the Berzelian nomenclature the protoxide of iron is *ferrous oxide,* the sesquioxide of the same metal *ferric oxide,* from ferrum, the Latin for iron. He applies this mode of distinction to all the binary compounds of his halogen and amphigen bodies. Thus, we have antimonious chloride, and antimonic chloride; signifying that the latter contains a larger proportion of chlorine than the former. Again, phosphorous bromide, and phosphoric bromide; phosphorous iodide, and phosphoric iodide; in which case, as in the other, the termination in *ic*, indicates a larger proportion of the more electro-negative ingredient. But the termination in *ide*, is only resorted to by him, where the radical is electro-negative; that is, in other words, when its oxides go to the positive pole. When the radical is one of those bodies which, when oxidized, go to the negative pole, the termination in *ure* is resorted to; hence, ferrous and ferric "*cyanures*," and ferrous and ferric "*chlorures*." I object to this complicated nomenclature, as founded on the error of not allowing those characteristics of acids and bases which have been acted upon by chemists in general, and by Berzelius himself in the case of oxacids and oxibases, to extend to the binary compounds formed by the bodies of the halogen class.

I consider the yellow salt in question, as consisting of a cyanacid containing an atom of cyanogen and an atom of iron, and which I would call *cyanoferrous* acid, united to a cyanobase of potassium, consisting of one atom of cyanogen, and one atom of potassium, and forming a *cyanoferrite of potassium*. The double salt, consisting of the same elements, but containing both in the acid and base, half an atom more of cyanogen, should, by analogy with the oxacids, have its acid distinguished by the name of *cyanoferric acid*, and should itself be called *cyanoferrate of potassium*.

Of Cyanic, Cyanuric, and Fulminic Acids.

An atom of cyanogen, combined with an atom of oxygen, forms *cyanic acid*, which may be obtained in union with potash, by igniting peroxide of manganese with ferroprussiate of potash, or cyanoferrite of potassium; being the salt alluded to above, as consisting of cyanogen, iron, and potassium. The cyanogen and potassium are converted, by the excess of oxygen in the manganese, into cyanic acid and potash, which unite, forming a cyanate of potash. Cyanic acid cannot, however, be obtained from the cyanates, in consequence of its extreme susceptibility of decomposition.

A crystalline substance may be procured from human urine, which is known by the name of urea. It consists of carbon, nitrogen, oxygen, and hydrogen, in the proportion to form one atom of cyanic acid, one atom of ammonia, and one atom of water. When urea is subjected to heat, ammonia escapes, and an acid remains, which was supposed to consist of one atom of cyanogen, and two atoms of oxygen. But it has been recently ascertained by Wohler and Liebig, that it consists of the elements of cyanic acid, chemically united to the elements of water; an atom of hydrogen, and an additional atom of oxygen, entering into its composition, not as water, but as essential constituents. Under these impressions, a new name, *cyanuric*, was given to it. This acid is solid, fixed, inodorous, and nearly tasteless. By combining with two atoms of water, as water of crystallization, it becomes capable of forming large crystals.

When anhydrous cyanuric acid is exposed, in a glass retort, to a low red heat, the extricated vapours being collected in a receiver refrigerated by a freezing mixture, hydrous cyanic acid is obtained. This acid and cyanuric acid consist of the same elements in the same proportion, but possess different properties and atomic weights. Hydrous cyanic acid is a colourless, volatile liquid, possessing a penetrating odour resembling that of acetic acid. It vesicates the skin when applied to it, exciting intense pain. Its vapour reddens litmus paper, is inflammable, and so pungent as uce tears, and cause severe pain in the hands. Cyanuric acid is comparatively inert in these respects, but is far less susceptible of decomposition; as it is not decomposed by solution in boiling nitric or sulphuric acid, while hydrous cyanic acid is decomposed by the addition of water.

Hydrous cyanic acid, at the ordinary temperature of the air, spontaneously undergoes an explosive decomposition, attended by an evolution of heat, and is converted into a solid mass of dazzling whiteness. This mass consists of a variety of cyanuric acid, which differs from that above described, in being insoluble in water or nitric acid, and in being decomposed by sulphuric acid. It is, therefore, to be considered as presenting a case of isomerism.

It is remarkable that, although cyanuric acid consists of the same elements in the same proportion as hydrous cyanic acid, it carries the hydrogen and oxygen which exist in it in the proportion to form water, into every combination which it forms; while the hydrous cyanic acid, in combining with bases, separates from the water, which must be considered, when in union with this acid, as acting as a base.

To bodies which, although they contain the same elements in the same ratio, yet hold them differently associated, so that in reacting with other agents, they are resolved into, or form compounds differing in composition, the term *metameric* has been applied. Thus, hydrous cyanic, and cyanuric acid are said to be metameric with regard to each other.

Another compound of cyanogen with oxygen exists in the fulminating mercury of Howard, and the analogous fulminating silver of Descotils. Liebig ascertained these compounds to contain an acid common to both, which he called *fulminic acid*, but which, agreeably to the analysis made by him and Gay-Lussac, was identified in composition with cyanic acid. Yet, as the latter would not produce fulminating compounds, and differed in its other properties, these acids have been considered as affording another instance of isomerism. Mr. Edmund Davy, however, alleges the existence of nitrogen in excess, and hydrogen in fulminic acid.

Fulminic acid is a colourless, transparent, volatile liquid, which reddens litmus, and produces a taste at first sweet, but afterwards astringent and disagreeable. Its fumes have a pungent and disagreeable odour, and produce headach when incautiously inhaled.

Besides these acids, M. Liebig has recently discovered another, which is polymeric with regard to cyanuric acid; as it consists of the same elements in the same ratio, though twice as much of each enters into the composition of an atom.

Of the Chlorides, Bromides, and Iodides of Cyanogen.

Chlorine forms two compounds with cyanogen, a protochloride and a perchloride. The *protochloride* is a colourless, fetid gas, which may be liquefied, and even solidified by cold. In common with several other compounds of cyanogen, it possesses, even when gaseous, the singular property of producing pain by contact with the skin. The *perchloride* is a white crystalline substance, with an odour resembling that of mice.

Bromine and iodine both form with cyanogen, crystalline compounds. The chlorides and bromides of cyanogen are energetic poisons.

Of Sulphocyanogen.

It has been stated that the yellow salt, usually known as ferroprussiate of potash, is by Berzelius considered, when free from water, as consisting of cyanogen, iron, and potassium; also that I consider it as a cyanoferrite of the cyanobase of potassium. When this salt, desiccated to efflorescence and finely pulverized, is mingled with flowers of sulphur, and exposed to a red heat in a porcelain crucible, the iron is displaced; the sulphur and cyanogen uniting, form a compound called sulphocyanogen, and this uniting with the potassium, constitutes a sulphocyanide.

Sulphocyanogen has been isolated by passing chlorine through a solution of sulphocyanide of potassium, or by subjecting that compound to nitric acid. Berzelius considers sulphocyanogen as one of his halogen bodies.

The intense blood-red colour which it produces with iron, is the most striking property of sulphocyanogen, and has led to the impression that the sulphocyanide of iron may be the colouring matter of the blood.

Sulphocyanogen is solid, insoluble in water or alcohol, and may, in its anhydrous state, be sublimed without change. It is composed of one atom of cyanogen, and two atoms of sulphur.

Dr. Thomson states that another compound of sulphur and cyanogen exists, containing one atom of sulphur and two atoms of cyanogen. This compound may be obtained in transparent colourless crystals. It is volatile, possesses a strong smell, and is soluble in water. When applied to the tongue, even in a minute quantity, it produces intense pain; and the part touched remains red and painful for some time.

Of Sulphocyanhydric Acid.

This acid may be obtained from a solution of the sulphocyanide of potassium, by the addition of phosphoric acid. Water is decomposed, the oxygen unites with the potassium, forming potash, with which the phosphoric acid combines, and the hydrogen with the sulphocyanogen, forming sulphocyanhydric acid, which may be separated by distillation. This acid is liquid and colourless, has an acid taste, and powerful odour. It becomes solid at 14°, and boils at 216°. It is composed of one atom of sulphocyanogen, and one atom of hydrogen.

Of Cyanhydric or Prussic Acid.

One atom of cyanogen, equivalent 26, with one atom of hydrogen, equivalent 1, forms one atom of cyanhydric acid, equivalent 27.

This acid has been detected in water distilled from bitter almonds and from laurel leaves, also, from peach leaves or blossoms. Between the odour of these, and that of the acid when dilute, it would be difficult to discriminate.

Laurel water has long been known as a poison. Water distilled from peach leaves has been used to impart an agreeable flavour to food. Some peach leaf water, prepared by Mr. Wetherill, gave indications of cyanhydric acid, by producing a blue colour with a solution of iron.

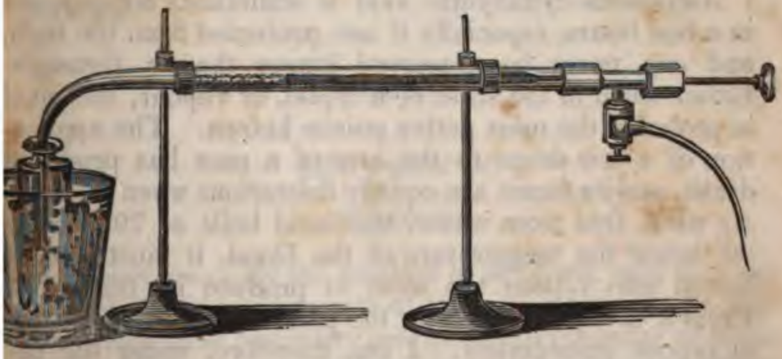
There have been instances in which noyeau, a cordial made from the kernels of bitter almonds, has proved poisonous from the presence of cyanhydric acid.

There is a salt consisting of two atoms of cyanogen and one of mercury, called bicyanide of mercury. When this salt is subjected to the action of chlorohydric acid, the chlorine forms a chloride with the mercury, while the hydrogen forms cyanhydric acid with the cyanogen.

It may be more conveniently obtained by impregnating with sulphydric acid, a solution containing sixty grains of bicyanide of mercury for every ounce of water. The hydrogen unites with the cyanogen, while the sulphur precipitates with the metal. Any excess of the sulphydric acid is easily removed by the carbonate of lead. The apparatus for impregnation with sulphydric acid, has been described already, page 211.

The acid may be procured in its most concentrated form, by exposing the bicyanide in crystals, in a tube, to sulphydric acid gas, and employing a receiver, surrounded by salt and snow, to condense the vapour evolved.

236. *Apparatus for the Evolution of Cyanhydric or Prussic Acid.*



Let a tube, three-fourths of an inch in bore and about two feet in length, be bent at right angles, at about six inches distance from one end. Let the shorter portion be drawn out into a tapering form, with a bore not exceeding a tenth of an inch in diameter. Upon the larger orifice let a brass band be cemented, in which a female screw has been cut, so that a stuffing box, furnished with a corresponding male screw, may be easily fastened ir-tight to the band, or removed when desirable. Through the stuffing box an iron rod passes, flattened like an oar at the end, which is within the ube when the stuffing box is in its place. There must likewise be a late-al aperture in the band communicating with the cavity of the tube, and urnished with a gallows screw. The main body of the tube is to be si ated nearly level, yet a little inclined towards the curvature, so that the tapering extremity may descend nearly perpendicularly into a tall narrow phial, surrounded by a freezing mixture. The horizontal portion of the tube near the bend should likewise be refrigerated. The apparatus being thus arranged, introduce a sufficient quantity of the bicyanide of mercury into the tube, and close it by inserting the stuffing box with its rod. In the next place, by means of the gallows screw, make a communication between the cavity of the tube, and a self-regulating reservoir of sulphydric acid. This gas must be allowed to pass into the tube very slowly, and meanwhile, by means of the rod, the bicyanide is to be stirred. Before long a portion of the cyanhydric acid will be seen in the narrow part of the tube. This serves to regulate the admission of the sulphydric acid, since, when the quantity passing into the tube is inadequate, the liquid will rise in the tube; when too great, it will be expelled from it. By these means, after a little while, all the bicyanide will be decomposed, and a corresponding quantity of acid collected in the refrigerated phial.

Properties of Cyanhydric Acid.—This acid is a colourless liquid, which emits a powerful odour, resembling that of peach blossoms. When perfectly free from water, it is far more volatile than ether, as it boils at 79° F., and evaporates so rapidly, that one portion becomes frozen by the loss of the caloric which the other absorbs in passing into the aëriform state. Its specific gravity is 0.7058, being nearly the same as that of sulphuric ether.

Anhydrous cyanhydric acid is sometimes decomposed in a few hours, especially if not protected from the light, and can never be preserved longer than a fortnight. Either when in the state of a liquid, or vapour, this acid is probably the most active poison known. The application of a few drops to the arm of a man has produced death, and its fumes are equally deleterious when inspired. As when free from water, this acid boils at 79°, nearly 20° below the temperature of the blood, it must be converted into vapour too soon to produce its full effect. From a cavity like the ear, the pure acid must be ejected in vapour immediately. I am, therefore, under the impression that it is less effectual as a poison when anhydrous, than when combined with a minute proportion of water.

Upon one occasion, touching the ear of a rat confined in a glass jar with a drop of the anhydrous acid, the animal, being obliged to breathe the vapour, died instantaneously with a slight sneezing. Yet upon another occasion I injected nearly half a drachm into the ear of a large dog without killing him. I afterwards killed him by injecting a like quantity into his nose. The acid employed was so pure as to freeze by its own evaporation.

The best remedy for it is an aqueous solution of chlorine, or, where that is not to be had, ammonia.

Cyanhydric acid is sometimes employed in medicine, though in very small doses, and in a very diluted state.

It has been proposed to detect cyanhydric acid, in cases in which it may have been employed in poisoning, by subjecting the stomach and its contents to distillation with water, and testing the liquid product by copper or iron.

I should place much reliance on the characteristic smell of the acid, which is that of peach blossoms, and which may be perceived, not only from the presence of the acid, but likewise from that of any of the cyanides, if subjected to the action of chlorohydric acid.

237. *Experimental Illustrations.*

The processes for the production both of the aqueous and anhydrous cyanhydric acid, exhibited; also, the congelation of the latter by the cold arising from its own evaporation.

◆

SECTION V.

OF BORON.

Preparation.—By the addition of sulphuric acid to a saturated solution of biborate of soda (borax) in water, shining crystalline plates are precipitated, consisting of boric acid. From these crystals boron may be obtained, either by the action of a powerful Voltaic series, or by first vitrifying them, then finely pulverizing the resulting glass, and afterwards heating the acid thus prepared in contact with potassium.

Boron may be obtained by means of the apparatus employed for the evolution of silicon, described page 301, substituting fluoboric acid gas for fluosilicic acid gas.

Properties.—Boron is of a dark olive colour, tasteless, inodorous, a non-conductor of electricity, and insoluble either in alcohol, ether, or the oils. Its atomic weight is 11. It is susceptible neither of fusion nor volatilization. When heated in the air to 600° F., it takes fire, and, by uniting with oxygen, generates boric acid. Nevertheless only a portion of the boron is oxidized, the remainder being protected by a crust of fused boric acid. If this crust be removed by water, the boron will be found to have undergone a change similar to that produced in charcoal by an intensely high temperature. It is rendered harder, more difficult to ignite, and so much denser, that, although its specific gravity was before only 1.83, it now sinks rapidly in sulphuric acid of the specific gravity of 1.844. Before it has been ignited, boron is slightly soluble in water; and its solution, when evaporated to a certain point, forms a gelatinous mass, which, by complete desiccation, becomes opaque, and assumes the usual appearance of boron.

COMPOUND OF BORON WITH OXYGEN.

Of Boric or Boracic Acid.*

The means of procuring this acid have been mentioned in describing the process for obtaining boron. Borax is a biborate of soda, from which boric acid may be liberated in crystals, as above described, by the superior affinity of sulphuric acid for the soda.

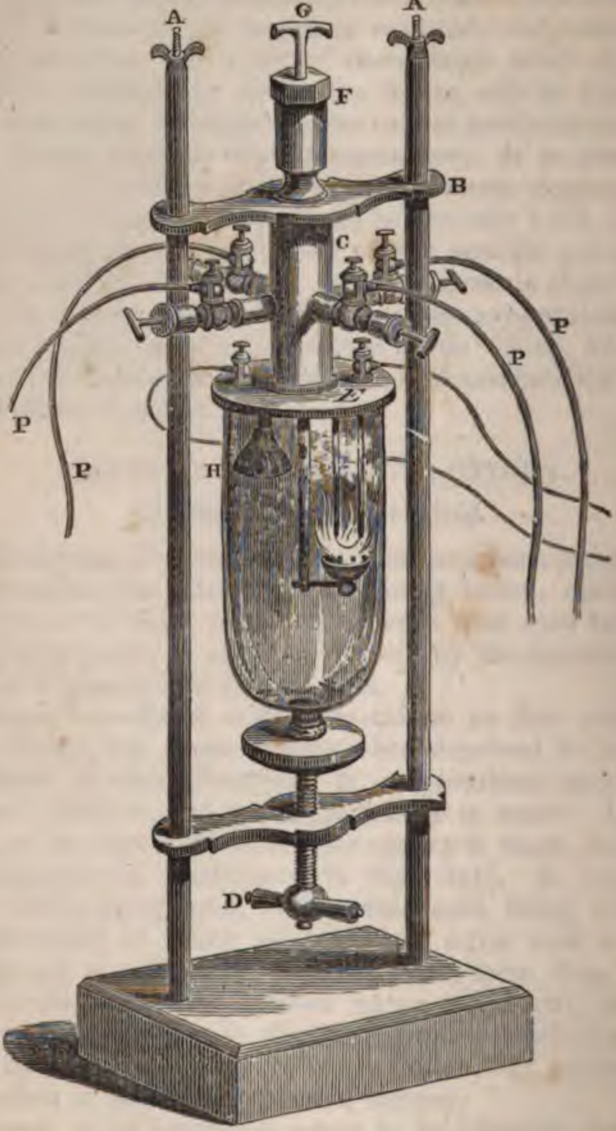
Properties.—Boric acid is crystalline as first obtained from borax, but forms a glass when deprived by heat of its water of crystallization. It is colourless, inodorous, almost tasteless, and sparingly soluble in water. In the form of an aqueous solution, its agency is weak, and it is in consequence rarely used in that state. In common with silicic, phosphoric, and arsenic acid, being fixed at temperatures at which sulphuric and nitric acid are decomposed, it will at those heats expel them from their combinations; although, when water is present, and at low temperatures, it is displaced from combination not only by those acids, but by many others. It consists of one atom of boron, and three of oxygen.

Boron, in its habitudes, seems to lie between phospho-

---

* I agree with the French chemists and Berzelius, in employing the word *boric* instead of *boracic*, as more naturally generated from boron, by analogy with the other acids formed with radicals, to the last letter of which the letters *ic* are usually added.

Apparatus for the Evolution of Silicon.



and carbon. In its insusceptibility of volatilization, sibility, and the temperature requisite for its combus-, it is most allied to carbon; yet boric acid is more logous to phosphoric than to carbonic acid. Both sphoric and boric acid are capable of being reduced vitreous state, and bear a white heat without being tilized; while the acid of carbon is naturally aëriform. oric acid and the biborate of soda are of great use in vpipe assays, as fluxes, and in soldering, as the means rotecting metallic surfaces from oxidation.

238. *Experimental Illustrations.*

aturated solution of borax, decomposed by sulphuric l. Exhibition of crystals of the acid and of the bibo-, which are severally fused into a glass by the com-nd blowpipe. Effects of cobalt and manganese upon colour of the glass, of which a globule is conveniently ported by a platinum wire.

Of Chloride of Boron.

ie chloride of boron may be obtained by the combustion of boron in ine; or by passing a current of chlorine over a mixture of charcoal boric acid, heated to redness in a porcelain tube.

he chloride of boron is a colourless gas, possessing a strong and pe-r smell. When brought in contact with water, a reciprocal decom-ion takes place, and boric and chlorohydric acid result. It forms a salt with ammonia, and is by some chemists considered as an acid.

◆

SECTION VI.

OF SILICON.

reparation.—By heating sulphuric acid with a mixture powdered Derbyshire spar, and powdered glass or rtz, a permanent gas may be obtained. When potas-n is heated in this gas, silicon is evolved.

Apparatus for evolving Silicon from Fluosilicic Acid Gas by means of Potassium.

his apparatus is represented by the opposite engraving. Into a stout ogany block as a basis, two iron rods, A, planted as tend perpendicularly, and of course parall about two feet in height. Upon these rods, two iron bars are supported horizontally, one B, near their upper extremities, the other, at the height of about six inches from the wooden basis. In the centre of the lower bar, there is a screw, D, having a handle below the bar, and supporting above it a circular wooden block. Into a hole in the upper iron bar, equidistant from the rods, is inserted a hollow brass cylinder, C, which at the lower end screws into an aperture in a circular plate of brass, E, which is thus supported horizontally a few inches below the bar. By these means, room is allowed for the insertion into the cylinder of four valve cocks, each furnished with a gallows screw. The cylinder is surmounted by a stuffing box, F, through which a copper sliding rod, G, passes air-tight. The brass plate is turned and ground to fit a bell glass of about five inches in diameter, and eight inches in height, which is pressed up when necessary between the plate and the block, by the screw, D, supporting the block. Within the space comprised by the bell glass, and on one side of the centre of the plate, two stout brass wires are inserted, one of them insulated by a collar of leathers, so as to admit of the ignition, by a galvanic discharge, of a small arch of platinum wire, which reaches from one to the other. The sliding rod above mentioned as occupying the stuffing box, terminates below the plate in an elbow which supports a cup at right angles to the rod, at the same distance from the rod as the platinum wire; and on the opposite side of it, there is a brass cover, H, for the cup, supported from the plate. The arrangement is such, that by a suitable movement in the sliding rod, made by grasping it by the handle, G, in which it terminates externally, the cup may be made either to receive into its cavity the platinum wire, or to adjust itself to its cover, H.

The bell being removed, about sixty grains of potassium, in pieces not containing more than fifteen grains each, are to be introduced into the cup, which is then to be adjusted to the cover, and the bell secured. In the next place, by means of the flexible lead tubes, P, P, P, P, and the gallows screws attached to the valve cocks, establish a communication severally with an air pump, a self regulating reservoir of hydrogen, a barometer gauge, and a jar over the mercurial cistern, containing fluosilicic acid gas. First, by means of the air pump, exhaust the bell, and, in order to wash out all remains of atmospheric air, admit hydrogen from the reservoir. Again exhaust, and again admit hydrogen. Lastly, exhaust the bell of hydrogen, and admit the fluosilicic acid gas. By means of the gauge, the exhaustion is indicated and measured, and by the same means it will be seen when the pressure of the gas within the bell approaches that of the atmosphere. When this takes place, the cocks being all closed, and by means of the process of galvano-ignition, (**111**, **183**,) the platinum wire being rendered incandescent, the potassium is to be brought into contact with it. A peculiar deep red combustion ensues, evolving copiously chocolate-coloured fumes, which condensing into flocks of the same hue, descend throughout the receiver, and are deposited upon the interior surface, so as to create in the mind of the spectator, the idea of a miniature fall of chocolate-coloured snow. On removing the bell after the potassium has ceased to burn, the cup which held it is found to contain silicon mixed with the fluoride of potassium, and with this the whole of the chocolate-coloured deposition is contaminated. Siliciuret of potassium is likewise found in the cup; since, upon the affusion of water, a fetid inflammable gas is evolved, which has an odour resembling that of phosphoretted hydrogen, and which must obviously be the analogous compound siliciuretted hydro-

n. The silicon, being insoluble, may be separated from the fluoride by gestion in water. When the potassium employed is of the kind obined by means of charcoal, the silicon is, as Berzelius alleges, adulteted with carbon. I am under the impression that strong nitric acid reoves this impurity.

Properties of Silicon.—It is of a brown-ash colour, ithout the least trace of metallic lustre, a non-conductor f electricity, infusible, and incapable of being volatilized. t is not liable to be dissolved or oxidized by sulphuric, itric, chlorohydric, or fluohydric acid, but is soluble in a ixture of nitric and fluohydric acid. When heated to edness with the fixed alkaline carbonates, it burns vividy; and when dropped upon the hydrates of potash, soda, r baryta, while in a state of fusion, it explodes. Yet it s unchanged by ignition with chlorate of potash, and exrcises but a feeble reaction with nitre, even when heated o redness. In these respects its habitudes are anomaous.

When silicon, as usually obtained by the aid of potasium, is intensely heated in the air or in oxygen gas, it urns with a feeble blue flame; but, by becoming encrustd with silicic acid, a portion escapes combustion. This ortion is rendered harder, denser, and insusceptible of ombustion with oxygen at the highest temperatures. erzelius suspects the greater combustibility, and inferior ensity and hardness of silicon, in the state in which it is btained by the process above described, to be due to the resence of hydrogen, derived from the water employed. n this state, it inflames when ignited in the vapour of ulphur, and forms a sulphide, which is decomposed by ater into sulphydric and silicic acid.

COMPOUND OF SILICON WITH OXYGEN.

Of Silica, or Silicic Acid.

One atom of silicon with one atom of oxygen, each quivalent to 8, forms one atom of silicic acid, equivaent 16.

Preparation.—Quartz being powdered, and fused with hree times its weight of pearlash, a glass is obtained, hich, being soluble, forms with water a liquid, called ormerly liquor silicum, or liquor of flints. An acid being oured into this solution, silicic acid, slightly contamiated by potash, is precipitated.

To obtain silicic acid, Berzelius advises us to fuse in a platinum crucible, equal parts of the carbonates of potash and soda, and to add quartz, finely pulverized, in small successive portions. The effervescence arising from the addition of one portion, is allowed to subside before adding another, until effervescence can no longer be excited. The refrigerated mass is dissolved in chlorohydric acid, and the solution filtered and evaporated to dryness. To remove all traces of iron or alumina, the dry mass is kept moist with chlorohydric acid, during about two hours, and afterwards washed with hot water, and then exposed to a red heat. Silicic acid will remain in a sufficient degree of purity.

Pure silicic acid, in the well known form of rock crystal, is found throughout nature. Its usual crystalline form is a six-sided prism, terminated by a pyramid with six faces.

Properties.—Pure silicic acid is white, tasteless, and inodorous, and has a specific gravity of 2.66. Its solution does not redden litmus, and, when evaporated to a certain point, forms a translucent jelly. It is soluble when nascent, but insoluble after exposure to heat or desiccation, or in its native crystalline form.

It was first fused by myself, in the year 1801, by means of the compound blowpipe. It has never been volatilized.

Of Chloride of Silicon.

When silicon is heated in chlorine it inflames, evolving heat and light, and a chloride of silicon is formed.

It is a volatile liquid, possessing a sharp and powerful odour. In consequence of the absorption of an excess of chlorine, it is generally coloured yellow. It boils below 212°, and, by the addition of water, is converted into chlorohydric and silicic acid.

240. *Experimental Illustrations.*

Silicate of potash, exhibited; also the solution of it, called liquor silicum, from which silica is precipitated by means of an acid.

Of Glass.

If the proportions, in which sand and alkali are used as above menti [illegible] the liquor silicum, be reversed, the insoluble compound of silicic acid and alkali, known under the name of glass, is obtained, which, however pure the materials, has a slight tinge of green. This is removed by a due admixture of the red oxide of lead, and black oxide of manganese.

Annealing Process.—A sudden diminution of the quantity of caloric among the exterior particles of a thick piece of glass in a state of ignition, is not attended by a corresponding diminution of the quantity of this principle among the particles within, owing to the slowness with which glass conducts heat. Hence, there can neither be a general coherence, nor a uniform arrangement among the particles; unless the cooling be very slow, so as to allow the refrigeration, within and without, to be nearly simultaneous. As it never can be perfectly simultaneous, the annealing will always be defective, other things being equal, in proportion as the glass is thicker. Were the particles subjected to radiant heat only, the process would be more effectual; as this, when proceeding from incandescent surfaces, has been ascertained to penetrate and even to pass through glass.

By gradually making up a fire of charcoal, at about four inches distance on each side of a glass tube of about an inch and a quarter in thickness, and with a very small bore, I was enabled to heat it red-hot, without causing a fracture. From its situation, it was subjected to radiant heat only.

Prince Rupert's Drops.—When glass, in a state of fusion, is dropped into water, the defective states of cohesion and arrangement, consequent to the want of annealing, are at the maximum. Such drops have long been known under the name of Prince Rupert's drops. It is only necessary to break off the slender filament in which the mass terminates, in order to cause an explosive dispersion of the whole into a coarse powder.

The cohesion of the particles in glass tubes, is often nearly as imperfect as in Prince Rupert's drops. The slightest mark from a file on the interior surface, or even wiping them out, especially if a metallic wire be employed, may cause them to break into pieces. Sometimes the fracture ensues immediately, at other times, not till many hours have intervened.

COMPOUNDS OF FLUORINE WITH HYDROGEN, BORON, AND SILICON.

Fluorine was cursorily noticed at page 177. As the theoretic grounds upon which its existence is assumed, cannot be elucidated without a reference to the compounds which it forms with hydrogen, boron, and silicon, I deferred treating of these compounds until the student should be acquainted with those substances.

The three compounds referred to are all acids, called *fluohydric*, *fluoboric*, and *fluosilicic acid*.

Of Fluohydric Acid, generally called Hydrofluoric Acid.

It is supposed that fluorine exists in nature in union with the metals of the earths and alkalies, especially with calcium, a metal of which lime is the oxide. Such compounds are called fluorides. The remarkable mineral, called Derbyshire or fluor spar, is viewed as a fluoride

Not long since, Derbyshire spar was considered a cor with an acid, called fluoric acid, and supposed to consist of oxygen and an unknown radical. Mr. Ampere first suggested the present doctrine, which was soon adopted by Sir H. Davy, and is now, I believe, almost universally sanctioned.

Preparation.—When fluoride of calcium is pulverized, and heated in a leaden retort with twice its weight of concentrated sulphuric acid, the water in combination with the acid is decomposed. The oxygen and acid form sulphate of lime with the calcium; while the hydrogen produces with the fluorine, fluohydric acid, which passes over in the form of a very volatile acid vapour, and may be condensed in a leaden or silver receiver, surrounded by a mixture of snow and salt. If received in water, it condenses without refrigeration, and forms a diluted acid.

Properties.—Fluohydric acid is a colourless, limpid liquid, which boils at a little below 60°. When anhydrous, its specific gravity is 1.0609. It is so volatile, that in a close apartment it cannot be decanted without subjecting the operator to intolerable fumes. This operation must be performed where there is a current of air to carry them off.

It ulcerates the skin with peculiar activity, and corrodes glass so as to trace its course indelibly, in running over the surface. It must be kept in vessels of silver or lead, accurately closed. When received in water it is absorbed, forming aqueous fluohydric acid, and is then more easily preserved.

One atom of hydrogen, equivalent 1, with one atom of fluorine, equivalent 18, is supposed to form one atom of fluohydric acid, equivalent 19.

241. *Experimental Illustrations.*

Powdered fluoride of calcium, heated with sulphuric acid in a leaden retort, adapted to a receiver surrounded by a mixture of snow and salt. Same process, substituting a receiver with water, by means of Knight's apparatus. Effect of fluohydric acid upon glass.

Of Fluoboric Acid.

Preparation.—It may be obtained by intensely heating a mixture of two parts of powdered fluoride of calcium, with one of vitrified boric acid, in an iron tube. One part of the boric acid is decomposed, the oxygen of which, and the remaining portion of the acid, form borate of lime with the calcium; while the boron unites with the fluorine, forming fluoboric acid gas, which must be received over mercury. Fluoboric acid gas, may likewise be procured, by heating in a glass retort two parts of fluoride of calcium and one of boric acid, with twelve parts of concentrated sulphuric acid. Berzelius, however, states that, when obtained by this method, it is contaminated by fluosilicic acid, arising from the action of the fluorine on the glass. This might, however, be avoided by performing the operation in a leaden retort.

Dr. Thomson states that the best method of obtaining fluoboric acid gas, is one which was suggested by Berzelius. Boric acid is to be dissolved in anhydrous fluohydric acid, and a gentle heat applied to the solution. A reciprocal decomposition takes place; the hydrogen of the fluohydric acid combines with the oxygen of the boric acid, forming water, while the fluorine unites with the boron, and constitutes fluoboric acid gas.

Properties.—Fluoboric acid is a colourless, transparent gas, with a potent odour, and an acid taste. It reddens litmus paper, and is destructive to life. Its specific gravity is 2.3622. Water absorbs seven hundred times its volume of this gas. When fluoboric acid is passed into water, the oxygen of a portion of the water unites with the boron, forming boric acid, while the hydrogen combines with the fluorine, producing fluohydric acid. The boric acid precipitates, and the fluohydric acid combines with the undecomposed portion of the fluoboric acid, forming a compound which Berzelius designates as hydrofluoboric acid, but which, according to the nomenclature which I have adopted, should be called *fluohydroboric* acid. If we continue to pass fluoboric acid gas into the water, or partially abstract this liquid by evaporation, until the solution of fluoboric acid becomes saturated, the affinities which were at first brought into play are reversed. The hydrogen of the fluohydric acid unites with the oxygen of the precipitated boric acid, and the fluorine with the boron; so that we finally obtain a simple solution of fluoboric acid in water. This solution is at first fuming; but on the application of heat it yields up a fifth part of its gas, and then strongly resembles concentrated sulphuric acid in appearance. Like that acid, it carbonizes organic products, in consequence of its affinity for water.

Three atoms of fluorine, equivalent 54, and one atom of boron, equivalent 11, form one atom of fluoboric acid, equivalent 65.

Of Fluosilicic Acid.

Preparation.—It may be obtained by adding to the materials for evolving fluohydric acid, one half their weight of finely powdered glass, subjecting the mixture to heat in a glass retort, and receiving the product over mercury; as by water it would be rapidly absorbed.

The oxygen of the silicic acid in the glass, with the sulphuric acid and calcium, forms a sulphate of lime; while the fluorine and silicon escape in the form of fluosilicic acid gas.

The apparatus which I employ for fluosilicic acid, is precisely the same as that described under the head of ammonia.

Properties.—Fluosilicic acid is a transparent, colourless gas, with a peculiar and suffocating odour, closely resembling that of chlorohydric acid. It reddens litmus paper, and has a specific gravity of 3.5735. When brought in contact with water it is rapidly absorbed, and a decomposition takes place, similar to that which ensues in the case of fluoboric acid under similar circumstances. Silicic acid is deposited in the form of a gelatinous mass, and fluohydric acid is produced, which combines with the undecomposed portion of the fluosilicic acid, forming a compound acid, to which, if it be an acid, I would give the name of *fluohydrosilicic*. If the water in combination with the fluohydrosilicic acid be partially removed by heat, fluosilicic acid gas escapes, leaving fluohydric acid in solution.

One atom of fluorine, equivalent 18, with one atom of silicon, equivalent 8, forms one atom of fluosilicic acid, equivalent 26.

242. *Experimental Illustrations.*

Production of fluosilicic acid, shown: also its absorption by water, and the precipitation of silicic acid, as above described.

Of the Reaction of Fluohydric Acid with Fluoboric and Fluosilicic Acid, and of the Nomenclature of the Compounds formed by the latter on meeting with Oxibases.

The union which ensues between fluohydric acid, and either fluoboric, or fluosilicic acid, agreeably to the preceding statement, may appear anomalous, in the way in which it has hitherto been treated. If, however, I am correct in my mode of defining the difference between an acid and a base, (page 252,) the combinations in question will not prove to be anomalous. I deem it consistent to suppose that a fluobase of hydrogen unites, in the one case with fluoboric acid, in the other with fluosilicic acid; so that fluohydroboric acid might be called fluoborate of the fluobase of hydrogen, or more briefly, fluoborate of hydrogen; and in like manner, fluohydrosilicic acid would be called fluosilicate of the fluobase of hydrogen, or briefly, fluosilicate of hydrogen.

When either fluohydroboric acid, or fluohydrosilicic acid, or in other words the fluoborate or fluosilicate of the fluobase of hydrogen, is brought into contact with an oxibase, the radical of the latter takes the place of the hydrogen, which, with its oxygen, forms water. Thus, in the case of potash, there would result a fluobase of potassium, usurping the place of the fluobase of hydrogen; and of course either a fluosilicate, or fluoborate of potassium must be formed. Agreeably to the Berzelian nomenclature, these compounds are double salts, the name of one being in the French translation, "*fluorure borico-potassique*," that of the other, "*fluorure silico-potassique*." Many analogous salts, formed by the acids under consideration with salifiable substances, are mentioned by Berzelius; also many others, in which other radicals, in union with fluorine, play a part analogous to that performed by silicon and boron, in the salts above mentioned.

There are instances in which compounds, usually called bases, act as acids. Of course it is consistent that compounds, usually called acids, should in some instances act as bases. In this respect, a striking analogy may be observed between the union of the oxide of hydrogen (water) with the oxacids and oxybases; and that of fluoride of hydrogen with fluacids and fluobases. According to Berzelius, water acts as a base to oxacids; as an acid to oxibases. So I conceive the fluoride of hydrogen acts as a base in the cases above noticed, while it acts as an acid in the compound of hydrogen, fluorine, and potassium, called by Berzelius "*fluorure potassique acide*." This compound I would call a fluohydrate of the fluobase of potassium, or more briefly, fluohydrate of potassium; as we say sulphate of copper, instead of the sulphate of the oxide (or oxybase) of copper.

SECTION VII.

OF ZIRCONION.

There is a stone, known under the name of the jargon or zircon of Ceylon, from which Klaproth extricated an earth, to which the name of zirconia was given. This earth is an oxide of an elementary body, which has been called zirconion, or zirconium. The termination in um is now only applied by chemists to the names of substances having the metallic character, and has been associated with the name of the element in question, under the erroneous impression, as I consider it, that the radical of zirconia is metallic. It appears to me to be deficient in two very essential characteristics of a metal; I mean metallic brilliancy, and the power of conducting electricity. Carbon, in the form of plumbago, has, in these respects, higher claim to the metallic character.

Zirconion appears to be sparingly distributed throughout the globe, and to have little practical utility. However, the following facts, by which its analogy with silicon and boron is demonstrated, appear to me highly interesting. When the hydrate of zirconia is subjected to fluohydric acid, the hydrogen combines with the oxygen, and the fluorine with the zirconion. The resulting fluoride I consider as fluozirconic acid; but it is one of the haloid salts of Berzelius, and is, by that chemist, designated as a "*fluorure.*" This "*fluorure*" combines with other "*fluorures,*" and thus forms, according to Berzelius, double salts, analogous to those formed by the same fluobases with fluoboric or fluosilicic acid. I consider the salts in question as fluozirconates; or in other words, as consisting of fluozirconic acid, and a fluobase.

The analogy thus displayed to boron and silicon, is an additional reason with me for not treating zirconion as a metal, and for not associating with its name that termination, which is employed generally to designate the metallic class.

Preparation.—It was from the fluozirconate of the fluobase of potassium, or what we may briefly call the fluozirconate of potassium, that zirconion was obtained by Berzelius, by heating this salt with potassium; in which case the superior affinity of this metal for fluorine, caused the zirconion to be liberated.

By an analogous process, silicon was obtained by this distinguished chemist from the fluosilicate of potassium.

The most striking difference between the properties of zirconion, and those of boron and silicon, is that these form acids with oxygen, while the oxide of zirconion acts usually as a base.

Properties.—As obtained by the process above mentioned, zirconion resembles charcoal powder, but is rendered impure by the presence of the hydrate of zirconia. This may be removed by the action of chlorohydric acid. Zirconion, when in a state of purity, is a black powder, which, by rubbing and pressure, may be made to unite in scales possessing a brilliancy approaching to that of plumbago. When heated in vacuo, and afterwards suffered to cool, it takes fire on the admission of air. Zirconion inflames in the air at a temperature considerably below that of redness, and is converted into zirconia. Its atomic weight is 34.

COMPOUND OF ZIRCONION WITH OXYGEN.

Of Zirconia.

Zirconia, when pure, is an infusible white powder, and is so hard as to scratch glass. When subjected to a violent heat it acquires a gray colour, and becomes harder, denser, and insoluble in acids. In this state its specific gravity is 4.3. It is composed of two atoms of zirconion, equivalent 68, and three atoms of oxygen, equivalent 24 = 92.

OF METALLIC RADICALS.*

It is to metallic radicals that I deem it expedient in the next place to direct attention. Less than thirty years ago, the line of demarcation between metals and other bodies was easily drawn. There was then no known metal which had a specific gravity less than six; and of other bodies, none, of which the specific gravity was as high as five. But the discovery of alkalifiable metallic radicals, having a specific gravity less than that of water, annihilated the barrier which had been established on the basis of superior gravity.

Peculiar brilliancy and opacity were in the next place appealed to as a mean of discrimination; and likewise that superiority in the power of conducting heat and electricity, which was so remarkable in substances of a decidedly metallic character. Yet so difficult has it been to draw the line between metallic and non-metallic radicals, that bodies which are by some authors placed in one class, are by others included in the other. Thus selenium, silicon, and zirconion have by some chemists been comprised among the metals, by others among non-metallic bodies. In fact nature has not qualified her bodies for distinct classification. It is true that there are those of which the prominent features or qualities are so strikingly different, that we are at first encouraged to think that by associating similar substances with each, we shall form classes not liable to be confounded. Thus gold possesses, in a high degree, all the attributes of a metal, while sulphur is totally devoid of them; yet arsenic, as being de-

---

* Dr. Hare includes all the metals under the head of metallic radicals, except tellurium, which he classes as a basacigen substance. B.

[illegible]

ate [illegible]
ma[illegible]
endow[illegible]
d into [illegible]
called [illegible]
shed from [illegible]
rom fire. [illegible]
a century [illegible]
of noble. [illegible]
ese platinum [illegible]
ium and [illegible]
considered [illegible]
e to which [illegible]
quently che[illegible]
metals wer[illegible]
own obvious [illegible]
oxides, whic[illegible]
h they are m[illegible]
. According [illegible]
a view to the[illegible]
racter of their [illegible]
e are some of [illegible]
, that there ca[illegible]
. Yet [illegible]
[illegible] by [illegible]
[illegible] that a diversity [illegible]
[illegible] to which they [illegible]
I propose to divide [illegible]
[illegible]ing classes:

First, *metals of the* [illegible]
Second, *metals of the* [illegible]
Third, *metals of the* [illegible]

Fourth, *metals proper*.

I shall employ the word noble to distinguish metals not liable to be tarnished by exposure to fire, water, or air; as, for instance, gold, platinum, silver, palladium, rhodium, and nickel.

Metals proper are by Berzelius divided into electro-negative or acidifiable metals, and electro-positive or basifiable metals. Under the former head he places selenium, arsenic, molybdenum, tungsten, antimony, tellurium, columbium or tantalum, and titanium. Under the head of electro-positive or basifiable metals, he places gold, platinum, osmium, iridium, palladium, silver, mercury, copper, bismuth, tin, lead, cadmium, zinc, nickel, cobalt, iron, manganese, and uranium.

I am under the impression that each of the following metals, being, agreeably to the same authority, capable of forming with a halogen[*] body the electro-negative ingredient in a double salt, should be considered as acidifiable; namely, gold, platinum, silver, palladium, iridium, rhodium, uranium, chromium, titanium, molybdenum, manganese, osmium, mercury, nickel, copper, iron, and zinc.

When the objects which it may be desirable to study, are too numerous and complicated in proportion to the time and attention which we have to bestow; we may employ such time as we have, either in a cursory, superficial, and indiscriminate examination of the whole, or in a more thorough study of the more important parts. Of the two courses I cannot conceive that any judicious person would hesitate in choosing the latter.

Under this impression I shall treat particularly of the twelve metals proper, included in the following list—gold, platinum, silver, mercury, copper, lead, tin, iron, zinc, antimony, bismuth, and arsenic. Besides the metals thus mentioned, there are in the same class, palladium, rhodium, iridium, osmium, nickel, cadmium, chromium, cobalt, columbium, manganese, molybdenum, titanium, tungsten, uranium, and vanadium. Of these I shall give only a brief account, with descriptions and illustrations of their striking and useful properties where such exist. Of tel-

---

[*] As a name distinguishing chlorine, bromine, fluorine, iodine, and cyanogen from the other basacigen bodies, is much wanted, I employ the word *halogen*, applied to those bodies by Berzelius, in honour of its author; although I do not concur in the opinions in which it originated.

I have already treated as a basacigen body, page

following table, taken from Turner's Chemistry, lition, shows the number of metals recognised at this and the periods at which they severally became , so far as those periods can be ascertained.

Table of the Discovery of the Metals.

es of Metals.	Authors of the discovery.	Dates of the Discovery.
	Known to the Ancients.	
y		
ny	Described by Basil Valentine	1490
h	Described by Agricola	1530
	First mentioned by Paracelsus	16th century.
	Brandt	1733
m	Wood, assay-master, Jamaica	1741
	Cronstedt	1751
nese	Gahn and Scheele	1774
en	D'Elhuyart	1781
um	Müller	1782
lenum	Hielm	1782
m	Klaproth	1789
m	Gregor	1791
ium	Vauquelin	1797
ium	Hatchett	1802
um	Wollaston	1803
m		
	Descotils and Smithson Tennant	1803
n	Smithson Tennant	1803
	Hisinger and Berzelius	1804
um	Davy	1807
um		
n		
um	Stromeyer	1818
n	Arfwedson	1818
ium	Wöhler	1828
ium		
n		
m	Berzelius	1829
sium	Bussy	1829
um	Sefström	1830

Of the Generic Characteristics of the Metals.

hen newly cut, metals have a peculiar lustre. They e best conductors of heat and electricity; the worst tors and best reflectors of heat. All combine, directly or indirectly, with oxygen, chlorine, and sulphur in one or more proportions, forming oxides, chlorides, and sulphides. Probably also they all may be combined with bromine, iodine, and cyanogen. They are all susceptible of solidity and fluidity, and probably of the aëriform state. Mercury and arsenic are easily volatilized; and gold, silver, and platinum, though very difficult to burn or volatilize, are nevertheless dissipated by means of the compound blowpipe, galvanism, or electricity.

Of Properties possessed by some Metals, but not by others.

The properties which come under this head, are permanency of lustre in the fire and air; malleability; ductility; elasticity; sensibility to the magnet; susceptibility of the welding process, and of acquiring, by a union with carbon, silicon, or aluminium, the capability of hardening by being suddenly refrigerated from a red heat; also of being hardened by the hammer, and of being restored by heat in the annealing process.

The metals remarkable for permanency of lustre, are gold, platinum, silver, and palladium, called on that account noble, or perfect. Those principally remarkable for malleability, are gold, silver, platinum, copper, palladium, iron, tin, lead, and nickel. Among these, iron and platinum only can be advantageously hammered at a very high temperature.

The metals distinguished for elasticity, are iron, copper, and silver. Iron, in the state of steel when duly tempered, is pre-eminent for this property.

The metals remarkable for ductility, are gold, iron, either pure, or as steel, silver, copper, platinum, tin, and lead. In large rods or pipes, lead and tin are the most ductile.

The magnetic metals are iron, whether pure, in the state of steel, or in that of protoxide, nickel, and cobalt. Those susceptible of the welding process, are iron and platinum. Iron only is capable of uniting with carbon, silicon, or aluminium, and hardening consequently by quick refrigeration. Gold and platinum are distinguished by their superior gravity, which is between two and a half, and three times as great as that of iron, tin, or zinc.

All the metals have a specific gravity greater than five, if we except those of the earths and alkalies.

Of the Annealing Process in the Case of Metals.

Malleability, ductility, and toughness, in metals susceptible of the annealing process, are probably dependent on the quantity of caloric remaining in combination with their particles, while in the solid state. When malleable metals are hammered, they give out heat, and become harder, more rigid, elastic, and dense, until they acquire a certain maximum of density. This being attained, they are fractured if the hammering be carried further. Exposed to the fire until softened, they are found on cooling to have regained the properties of which percussion had deprived them; and they may be again heated, hardened, and condensed by the hammer.

Of Alloys.

This name is given to the compounds formed by the union of different metals. There is always copper in gold and silver coin; and in the metal employed under those names by the smiths and jewellers, there are various proportions of the baser metal. Brass consists of copper and zinc; pewter, of lead and tin, or of tin, copper, and antimony.

Of the Oxidability of Metals by Exposure to Air or Moisture, with or without Heat.

Gold, silver, platinum palladium, and rhodium do not become oxidized by exposure to water or oxygen at any temperature; and when oxidized by other means, on being ignited are reduced.*

Iron, zinc, and tin are not oxidized by exposure to dry air, or to water alone, unless aided by a red heat. Of these metals, iron is most acted upon by the joint influence of air and moisture, at the ordinary temperatures of the atmosphere. Copper, tin, and lead do not decompose water at any temperature, but are oxidized at a red heat, or at temperatures sufficient for their fusion. Mercury is not oxidized by water under any circumstances. It is oxidized by agitation, or by a heat just below its boiling point; but when distilled, it abandons the oxygen which may have united with it previously.

---

* The verb to *reduce*, has long been employed by chemists to signify the deoxidizement of a metallic oxide, so as to effect its restoration to the metallic state, or that of a *regulus*, to use another word which I shall also employ, to avoid circumlocution; although it is now somewhat antiquated. The verb to *revive* has been used in the same sense as to reduce.

OF METALS OF THE EARTHS PROPER.

The metals included under this head are *aluminium*, *glucinium*, *yttrium*, and *thorium*.

SECTION I.

OF ALUMINIUM.

A chloride of aluminium was obtained by Oersted, by subjecting to a current of chlorine, an intimate mixture of alumina and carbon, heated in a porcelain tube. The affinity of the carbon for the oxygen of the earth, and of the chlorine for the metallic radical, was productive of carbonic oxide which escaped, and a chloride of aluminium which remained.

By heating, with potassium, the chloride obtained by the process above mentioned, Wöhler liberated aluminium through the superior affinity of potassium for chlorine. In this state, aluminium constitutes a gray powder much resembling that of platinum. Some little facets, which have sufficient magnitude to be distinguished, after compression under the burnisher, display a metallic brilliancy. Yet in the pulverulent form, the metal has so little power to conduct electricity, that, when interposed in the galvanic circuit, it interrupts the action. It is alleged, however, that, in a minute state of division, iron is a non-conductor of electricity, and Turner states that, by fusion, aluminium becomes a conductor. It appears to me that at best its claims to the metallic character are not superior to those of carbon in the form of plumbago. Its atomic weight is 14.

Aluminium burns with a heat so intense, as to cause the fusion of the resulting oxide, which becomes, on cooling, hard enough to cut glass. Aluminium is not oxidized when water is evaporated from it at a gentle heat. At a boiling heat it evolves hydrogen feebly, and the evolution, having once commenced, continues for some time after refrigeration. With concentrated nitric or sulphuric acid, aluminium has no reaction at ordinary temperatures; but, assisted by heat, it forms a sulphate or nitrate, acquiring oxygen from one portion of the acid, and uniting with the remainder. When subjected to a solution of potash, soda, or ammonia, aluminium, by the decomposition of the water, is converted into alumina, which unites with the alkali, forming an aluminate. On this account, in preparing aluminium, there should not be an excess of potassium; and any potash produced during the process, should be quickly removed by the employment of a quantity of water no larger than necessary.

Of Alumina.

This earth is found nearly pure in the gems called by ewellers oriental, and classed by Brongniart under the head of Corindon Telesie. The ruby, sapphire, amethyst, and topaz, of the most beautiful kinds, are thus designated. Of all stony minerals, they have the highest specific gravity, and are only inferior to the diamond in hardness. Differing from each other only in colour, they yield by analysis little else than pure alumina. There are other jewels of the same name and colour, which ought not to be confounded with those here alluded to. As an ingredient in clay, which owes its plasticity and all its striking qualities to alumina, this earth enters largely into the structure of the terrestrial globe.

There are two native forms of hydrate of alumina; one found in the United States, in the form of a stalactite, white and semitransparent, called Gibbsite; the other in Siberia, called diaspore, from the property of flying into pieces, or even powder, when heated, in consequence, no doubt, of the vaporization of the combined water.

Preparation.—Berzelius alleges that the alum of commerce, if it contain oxide of iron, should be dissolved and recrystallized several times; or a solution being made and allowed to stand for some time, the oxide of iron is precipitated in yellow flocks. To the solution of alum at a boiling heat, a solution of carbonate of potash is to be added in excess, and the whole is to be digested at a moderate temperature, to decompose any supersulphate of alumina which the alkali may have precipitated. The precipitate, after having been collected and well washed upon a filter, is to be redissolved in chlorohydric acid, and precipitated by an excess of ammonia, either caustic or carbonated. This second precipitation is necessary, to get rid of a portion of carbonate of potash, with which the alumina forms a triple combination which cannot be decomposed by water. The precipitate produced as last mentioned, is to be collected and carefully washed. When dried it forms a hydrate, which, by a red heat, is converted into pure alumina. One hundred parts of alum yield a little more than ten of the earth.

In France a species of alum is used, in which ammonia takes the place occupied by potash in the common alum. By heat, which expels the acid and alkali, pure alumina may be extricated from this compound.

Properties.—Alumina is white, plastic when moistened, soft to the touch, adherent to the tongue, inodorous, insipid, and infusible in the furnace. It is the only earth which was fused before the compound blowpipe was invented. Its property of contracting and hardening by heat, was noticed when on the subject of Wedgwood's pyrometer.

It is remarkable that, although quite insoluble in water, this earth abstracts and retains a quantity of water amounting to 15 per cent. of its weight. It is on this account that, as an ingredient in clay, its influence on vegetation is so beneficial. During rains it becomes saturated with moisture, which it slowly relinquishes in dry weather.

There is a remarkable difference in the appearance of the hydrate of alumina as obtained by precipitation from a concentrated, or a weak solution of alum. In the former case it is a white, friable, spongy powder, which is adherent to the tongue, and, by exposure to a red heat, parts with all its water. In the latter it forms a transparent yellow mass, which breaks by the heat of the hand with a smooth and conchoidal fracture, does not adhere to the tongue, or swell by the addition of water. In this state, the hydrate of alumina does not part with all its water, even at a temperature above that of redness.

Alumina has a great affinity for vegetable colouring matters, which it consequently precipitates from their solutions, forming the pigments known under the name of lakes.

Alumina is soluble in solutions of caustic potash and soda, and even in those of baryta and strontia, but dissolves in liquid ammonia, only to a very small extent. Alumina has an affinity so strong for oxybases, as to be considered as acting the part of an acid in some instances. With the acid and base of alkaline carbonates it forms triple compounds, which will bear a low red heat without expelling the acid, or producing a more inti-
union between the earth and alkali.

The spinelle ruby, a precious stone, and Gahnite, are aluminates,—the former of magnesia, the latter of zinc; in which, however, there are six times as many atoms of alumina, as of the other constituent. The affinity of alumina for magnesia is so strong that when separated simultaneously from a common solvent, the former cannot be taken up entirely by the alkali, by which the separation is effected. If magnesiferous alumina, after having experienced a red heat, be subjected to chlorohydric acid, a white powder remains, which is an aluminate of magnesia.

Three qualities serve to detect alumina; first, its affinity for potash, and consequent solubility in a solution of that alkali; secondly, the property which it has of forming with sulphuric acid and potash, alum, so readily recognised by its crystallization and taste; thirdly, the property of producing a fine blue colour, when moistened with nitrate of cobalt, and exposed to a strong heat.

This earth and its salts are of great use in dyeing, as mordants to cause the dyes to adhere. The latter in many cases have no affinity for the organic fibres which are to be dyed; but the alumina, combining with both the dye and the fibre, associates them permanently.

In the habitudes of this substance, we have an exemplification of the commutable character of electro-chemical characteristics. While with the alkalies and alkaline earths it performs the part of an acid, with various acids it acts as a base, forming with them compounds, both natural and artificial. Among the former is the mineral generally designated as feldspar, which is composed of silicate of alumina, and silicate of potash. Porcelain is an artificial silicate of alumina. Its existence as a base in alum has been mentioned.

Alumina was named from alumen, the Latin appellation for alum. The specific gravity of alumina is 2. It is composed of two atoms of aluminium, equivalent 28, and three atoms of oxygen, equivalent 24 = 52. It is, therefore, a sesquioxide.

243. *Experimental Illustrations.*

Alumina, precipitated from a solution of alum by an alkali. Rendered blue by a solution of nitrate of cobalt. Contraction sustained by exposure to heat, illustrated.

Of Chloride of Aluminium.

The chloride of aluminium is obtained as I have stated above. It is partially translucid, lamellated in structure, of a greenish-yellow-colour, and an astringent taste. Litmus is reddened by the action of this chloride. It dissolves in water with a hissing noise. When the solution is highly concentrated, it deposites crystals, which, being convertible by heat into alumina and chlorohydric acid, probably consist of one atom of chloride of aluminium, and one atom of water. According to Thenard, the chloride of aluminium forms, with the chlorides of potassium and sodium, compounds indecomposable by a red heat. These may be considered as formed by the union of a chloracid with a chlorobase.

With sulphur, selenium, and phosphorus, aluminium forms some unimportant compounds.

SECTION II.

OF GLUCINIUM.

Glucinium may be obtained from its oxide, glucina, by the same process as that above described for obtaining aluminium. It resembles aluminium in appearance, and in many of its properties, but differs from it in not being susceptible of oxidizement by a solution of ammonia, or by boiling water.

Of Glucina.

Glucina is white and tasteless. It is insoluble in water, but forms with it a paste, which is somewhat adhesive, but not sufficiently so to be moulded. It does not harden by exposure to heat.

It is soluble in the caustic fixed alkalies, but not in ammonia. It likewise dissolves in the alkaline carbonates, and in that of ammonia especially, by which it is distinguished from alumina, as well as by its incapacity to produce alum, or to assume a blue colour when treated with nitrate of cobalt. It forms also a fluacid, which, with the fluoride of potassium, precipitates from a hot solution in crystalline plates, in the state of ***fluoglucinate of potassium*** (fluoride glucinico-potassique of Berzelius).

The equivalent of glucina is 26, being composed of one atom of glucinium, equivalent 18, and one atom of oxygen, equivalent 8.

Glucina exists in the emerald, comprehending the beryl and aquamarine, and in the euclase. In consequence of the peculiar sweetness of its salts, it was named glucina, from γλυκυς, sweet.

SECTION III.

OF YTTRIUM.

Yttrium was procured by a process quite analogous to that described for aluminium. It has a more metallic and crystalline aspect than that metal or glucinium. Its habitudes with oxygen and the acids are perfectly analogous to those of the metals above mentioned. It is liable to be slowly oxidized in a solution of potash by the decomposition of water. Like glucinium, it is not oxidized by water even when boiling.

Of Yttria.

Yttria is insipid, infusible, and insoluble in water. It is uncertain whether the yellow tinge which it usually presents, is appropriate, or produced by impurities. It is rendered snow-white by the presence of a small quantity of sulphuric acid. It is heavier than baryta, being of a specific gravity approaching to 4.842. It is distinguished from other earths by its insolubility in caustic alkalies; while it dissolves in their carbonates, especially that of ammonia, although in a lesser quantity than glucina.

Yttria is principally characterized by its susceptibility of precipitation by cyanoferrite of potassium (ferroprussiate of potash). Excepting tho-
property is possessed by no other earth.

With acids it forms salts having a sweet taste, and in some instances the colour of the amethyst. In fact, the best means of detecting it, is the production with sulphuric acid of crystals having this hue, which are extremely slow to dissolve in water, and which effloresce when heated. Its affinities are more feeble than those of the alkalies or alkaline earths.

This earth has been found only in three Swedish minerals,—Gadolinite, yttro-tantalite, and yttro-cerite.

Yttrium is composed of one atom of yttrium, equivalent 32, and one atom of oxygen, equivalent 8 = 40.

◆

SECTION IV.

OF THORIUM.

Thorium was first found not many years since, in a single locality, in the state of oxide or earth, combined with silicic acid. It is in the island of Loecun that it was met with, near the little village of Berwig, in Norway. It was found in a mineral resembling obsidian, and called thorite, which contained 57 per cent. of thorina, or oxide of thorium, and in addition, lime, magnesia, iron, manganese, osmium, lead, tin, and a little alkali combined with silicic acid, and water. In making the analysis of this mineral, Berzelius discovered thorina.

From chloride of thorium, as from the other chlorides of the same metallic genus, the radical may be evolved by means of potassium and heat. It may likewise be extricated from the double fluoride of thorium and potassium, or fluothorate of potassium. Thorium, in its appearance and in many of its properties, much resembles aluminium; but differs from it in not being oxidized by reaction with boiling water, dilute sulphuric acid, or alkaline solutions. When heated gently in the air, thorium inflames, and is converted into thorina.

I do not conceive that either thorium, or any other of those substances enumerated as convertible by oxidizement into the earths proper, are more entitled to be considered as metals, than carbon in the state of plumbago.

Of Thorina.

Thorina is white, tasteless, and inodorous. In common with alumina, glucina, and yttria, it is capable of acting as a base with water. The resulting hydrate of thorina is by heat convertible into the anhydrous oxide, in a state of great hardness.

Thorina may be known from its sulphate being more soluble in cold than in hot water. · It is composed of one atom of thorium, equivalent 60, and one atom of oxygen, equivalent 8 = 68.

OF METALS OF THE ALKALINE EARTHS.

Under this head are included *magnesium*, *calcium*, *barium*, and *strontium*.

SECTION I.

OF MAGNESIUM.

Magnesium was first obtained by Bussy in 1829, by subjecting the chloride to the action of potassium, in a manner precisely similar to that already described for obtaining the metals of the earths. It resembles silver in colour and fusibility. It is malleable, and has a decided metallic brilliancy. It is oxidized by exposure to the air, or to boiling water. When sufficiently heated in the air, it combines with oxygen, and is converted into magnesia. Its specific gravity is greater than that of water.

Of Magnesia.

This earth, in a state of combination, exists in considerable quantities in nature. Dr. Thomson states that a whole range of low hills, consisting of anhydrous carbonate of magnesia, exist in India.

In the state of sulphate or Epsom salt, it is largely obtained from a mineral, found in Maryland and in Lancaster county, called magnesite, which is a silicate of magnesia, iron, and lime; also from the mother water of sea salt, resulting in the process of obtaining that chloride from the salt water of the ocean.

This earth may be precipitated from a solution of Epsom salt, by adding a solution of potash or soda. It may likewise be obtained from the carbonate by heat.

Properties.—Magnesia is white, has a feeble alkaline taste, and affects vegetable colours like an alkali, though feebly (215). It is nearly insoluble in pure water, but dissolves to a considerable extent in water containing carbonic acid, forming a soluble supercarbonate.

Magnesia is distinguished from the other alkaline earths, not only by being less energetic in its affinities and alkaline properties, but by the solubility of its sulphate.

Magnesia is one of the most fixed and refractory substances in nature, and was deemed infusible until fused by me in 1801, with the aid of the compound blowpipe. The specific gravity of magnesia is 2.3, and its equivalent, 20.

244. *Experimental Illustrations.*

The precipitation of magnesia from a solution of Epsom salt, exhibited; also its effects upon vegetable colours.

◆

SECTION II.

OF CALCIUM.

Calcium was obtained by Sir H. Davy, by negatively electrifying lime in contact with mercury. The earth was made into a paste with water, and formed into a small cup, in which a globule of mercury was placed. The cup being supported on a platinum dish, communicating with the positive pole of a galvanic battery, a wire of the same metal, proceeding from the other pole, was introduced into the mercury. After some time an amalgam of the metal of the earth was obtained. This amalgam was then subjected to heat in a glass tube filled with the vapour of naphtha, and hermetically sealed. The mercury was thus driven off, and the calcium obtained in a separate state.

Calcium is a white metal which inflames readily in the air, regenerating lime. Its properties are but imperfectly known. Its equivalent number is 20.

Of Lime.

This oxide exists largely in nature in combination with carbonic acid, forming all the varieties of marble and limestone. Some kinds of white marble, especially that of Carrara, so celebrated on account of its employment in statuary, consist solely of this earth combined with water and carbonic acid, uncontaminated by any other matter. The acid and water being expelled by heat, the lime remains in a state of purity. Oyster-shells yield very pure lime by heating them to incandescence.

When impure carbonates of lime are exposed to a very high temperature, the matter constituting the impurities is prone to enter into intimate combination with the lime, impairing its causticity, and susceptibility of the slaking process. No doubt this arises from a diminution of affinity for water. The lime of shells is sometimes partially converted into a sulphide, by sulphur derived from the animal matter.

The calcination requires more heat in a crucible, especially if covered, than in an open fire; and if the heat be too sudden, the carbonate may be fused without the expulsion of all the acid, which is afterwards more tenaciously retained. The extrication of the carbonic acid is promoted by a current of steam, or of any other aëriform fluid. But steam is preferable, as it is more easily procured, and cannot be productive of impurity. The rationale is that homogeneous aëriform particles interfere with each other more than heterogeneous, which, agreeably to the Daltonian doctrine, to a certain extent oppose no resistance to reciprocal intermixture and penetration.

After the first calcination, Berzelius recommends that the lime be slaked, and again calcined in an open crucible.

Lime is alleged to produce heat even when triturated with snow.

Properties.—The colour, taste, and smell of this earth are well exemplified in the best kinds of lime used in building (sometimes called quicklime), which is, strictly speaking, oxide of calcium, isolated from the water and carbonic acid usually united with it as found in nature. This has consequently the property of reacting with water, and producing the phenomena attendant on the process of slaking, during which lime combines with the water with which it is moistened, and becomes a hydrate. The caloric, which exists in the water as the cause of its fluidity, is evolved.

Water takes up about $\frac{1}{700}$th of its weight of this earth, forming lime-water. On this a pellicle is generated, as in the case of baryta, soon after exposure to the air, by the union of the lime with the carbonic acid which always exists in the atmosphere.

Lime-water dissolves some metallic oxides, those of lead and mercury especially, and operates on vegetable colours like an alkali.

Though lime is precipitated by carbonic acid in the state of carbonate, water impregnated with this acid dissolves the carbonate. Oxalic acid is the best test for lime. The fusion of this earth was first accomplished by me with the compound blowpipe in 1802. The specific gravity of lime is 2.3, and its equivalent, 28.

The hardening of mortar is ascribed by Berzelius to the affinity between the lime and silicic acid.

Phosphuret of calcium may be made by dropping phosphorus on caustic lime, ignited in a matrass with a long neck. An excess of phosphorus should be employed, and expelled by subsequent distillation. By the affusion of water, this phosphuret gives out phosphuretted hydrogen, which inflames spontaneously. This gas is still more actively evolved when the phosphuret is subjected to muriatic acid. Either chlorine or oxygen combines with the calcium, while the hydrogen of the acid or of water unites with a portion of the phosphorus, and assumes the gaseous form.

245. *Experimental Illustrations.*

Characteristic changes produced in vegetable colours by the solution of the earth in water, called lime-water. A glass of lime-water is not made turbid by air from a bellows, but becomes so on propelling the breath through it. Absorption of carbonic acid by lime-water, shown. Solution of lime by an excess of the acid. Lime precipitated from solutions of its muriate or nitrate, by sulphuric or oxalic acid.

Of Peroxide or Bioxide of Calcium.

Oxygen is absorbed when passed over lime heated to incandescence. By adding lime-water to oxygenated water, acidulated with muriatic acid, Thenard procured crystals of bioxide of calcium.

* * *

SECTION III.

OF BARIUM.

Barium is obtained from the earth baryta, by a process precisely similar to that for obtaining calcium from lime. It is a solid dark-gray metal, with a lustre somewhat inferior to that of cast iron. It is fusible and vaporizable at a heat below redness, and, when in a state of vapour, acts violently upon glass. Its specific gravity is such as to cause it to sink in sulphuric acid. It is rapidly oxidized in the air, and regenerates baryta when thrown into water. Its atomic weight is 69.

Of Baryta.

This earth was named from the Greek Βαρυς, heavy; because the minerals containing it are peculiarly heavy, when compared with other earthy substances.

Preparation.—To procure baryta, Berzelius advises that eight parts of the sulphate, finely pulverized, should be intimately mingled with one of charcoal, and afterwards triturated with two parts of resin, or wheat flour. The mixture is to be kept at a white heat, in a Hessian crucible, for three-quarters of an hour. The resin is serviceable by coating, while in fusion, all the surfaces of the sulphate, and, being subsequently carbonized, leaves every part of the compound in contact with carbon.

The sulphate of baryta, deprived of oxygen, becomes sulphuret of barium, which yields a nitrate of baryta on the addition of nitric acid. The filtered solution by evaporation yields crystals of the nitrate, which should be decomposed in a porcelain or platinum crucible. This operation is tedious; since the heat cannot be urged beyond a certain degree of intensity, without causing the salt to rise up in a foam, so as to overflow the crucible. If the heat be not applied long enough, Berzelius alleges that a portion of nitrous oxide remains united with the earth, forming a compound which has been mistaken for bioxide ("suroxide") of barium.

Neither the carbonates nor hydrates of baryta and strontia are, like those of lime, decomposable per se by heat. The addition of carbonaceous matter enables us to decompose them; as it changes the carbonic acid into carbonic oxide, which has no affinity for the earths, and, therefore, escapes.

Properties.—Baryta is acrid, slakes like lime, and is more soluble in water. It is more actively alkaline, both as respects its taste and its action on vegetable colours, than any other earth. It is gray at first, but absorbs rater and becomes white. Its aqueous solution is renered milky by carbonic acid, and, by combining with it, ecomes covered with a pellicle of carbonate, when exosed to the atmosphere. From its solution in boiling rater, baryta crystallizes on cooling.

Solutions of barium, whether in the state of a hydrate, itrate, or chloride, are very useful as tests for sulphuric cid, which, combining with the oxide of barium (baryta), reviously existing in the hydrate or nitrate, or formed rom the chloride by the decomposition of water, is preipitated by them from any liquid.

Ignited intensely, it absorbs oxygen if exposed to it, nd passes to the state of bioxide. This earth is poisonus. Its specific gravity is 4, and its equivalent, 77.

246. *Experimental Illustrations.*

Baryta, free from water, exhibited; also in crystals. Barytic water rendered milky by the carbonic acid of he breath. Solutions of baryta, and of sulphuric acid, ntroduced into distinct vessels of pure water, have no ffect; but portions mingled in the same vessel produce cloud. Water, coloured by alkanet, turmeric, &c., hanged by baryta, as by an alkali.

SECTION IV.

OF STRONTIUM.

Strontium is obtained from the earth strontia, by a process precisely similar to that by which calcium is procured from lime. It is a dark-gray metal, bearing a strong resemblance to barium. Its atomic weight is 44.

Of Strontia.

This earth is very analogous to baryta in its properties and composition. It is distinguished from baryta, by the red colour which its solutions communicate to flam by its crystallization, and by its being more boiling water and less so in cold. Excepting baryta, it is more actively alkaline than any other earth, both as respects taste and its action on vegetable colours.

Strontia may be obtained from the carbonate or sulphate, by a process in every respect similar to that which has been described as the means of procuring baryta.

The equivalent of this earth is 52.

247. *Experimental Illustrations.*

Turmeric, alkanet, and red cabbage, changed by strontia-water, as by alkalies. Red colour of the flame of alcohol containing strontia, shown.

Of the Peroxides or Bioxides of Barium and Strontium.

When the protoxides of barium and strontium are heated in contact with oxygen gas, they absorb it, and are converted into bioxides. When an aqueous solution of these earths is added to oxygenated water, the bioxides of their metallic radicals are precipitated in a crystalline form.

It was by means of the bioxide of barium, procured by exposing the protoxide, in a glass tube, to a current of dry oxygen gas, that Thenard was enabled to obtain *oxygenated water.*

The bioxide of barium was dissolved in chlorohydric acid. By adding sulphuric acid, sulphate of baryta was precipitated, in which half of the oxygen of the bioxide was retained, the other half being left in combination with the water of the solvent. This operation being repeated several times, the liquid became more and more surcharged with oxygen. Afterwards, the chlorine of the acid was precipitated by sulphate of silver, and the sulphuric acid, thus introduced, by baryta. Finally, the oxygenated water being less vaporizable than in its natural state, by placing the oxygenated liquid in an exhausted receiver over a vessel of sulphuric acid, the oxygen was concentrated, until the liquid held double the quantity essential to it as a protoxide of hydrogen.

ETALS OF THE ALKALIES, OR ALKALIFIABLE METALS.

this head *potassium*, *sodium*, and *lithium* are

SECTION I.

OF POTASSIUM.

iscovery of potassium and sodium was made by phry Davy, in 1807, by exposing their oxides, nd soda, to the divellent influence of the Voltaic These metals were afterwards obtained more y, by subjecting the alkalies, in contact with iron ded state, to intense heat in a luted gun barrel. farther improvement has been made by heating li intensely, while intermingled with charcoal.* lkaline metal, whether potassium or sodium, being at any temperature above redness, is extricated tate of vapour, and condensed in a part of the s where the heat is below redness.

rties.—Potassium, when newly cut, strongly re- silver in appearance. It is malleable, and so soft ry temperatures, as to be moulded between the ke wax. When cooled to 32° it becomes brittle, bits, when broken, a crystalline fracture. It melts and is converted into vapour when heated to a ow redness. When exposed to the air at the temperature, it absorbs oxygen rapidly, and is d into potash. This absorption is sometimes so specially when aided by friction, as to cause the tion of the potassium. I once lost half an ounce sium, in consequence of attempting to extricate it ng the bottle by a file; it took fire, and was en- idized. The affinity of this metal for oxygen is , that, when thrown upon water or ice, it com- h the oxygen; while the hydrogen takes up a cer- ion of the potassium, and burns with a beautiful ured flame. Potassium is lighter than water, its ravity being only 0.86. It is a good conductor nd electricity. Its atomic weight is 40.

---

* endix for my letter on Brunner's process for obtaining potassium.

SECTION II.

OF SODIUM.

Properties.—Sodium resembles potassium in its appearance, and in many of its properties. It retains its softness and malleability when cooled to 32°. A globule of sodium, thrown upon water, swims to and fro on the surface with great rapidity, absorbing oxygen, and evolving hydrogen from the water; yet no inflammation ensues. This is probably owing to the rapidity of its motion, which, by bringing it in contact with successive portions of water, keeps the temperature below that which is necessary to combustion; since, when the water is thickened with a little gum, which tends to impede the motion of the globule, sodium burns with a brilliant yellow flame. The presence of an acid produces the same result. The affinity of sodium for oxygen, does not appear to be so strong as that of potassium; since, according to Thenard, it is not oxidized when exposed to dry atmospheric air, or oxygen. It melts at 194°, and for volatilization, requires a higher temperature than potassium.

Sodium forms a number of alloys with potassium; one of these remains fluid at 32°, and is lighter than naphtha. The specific gravity of sodium is 0.97223. It is a good conductor of heat and electricity. Its atomic weight is 24.

248. *Experimental Illustrations.*

The inflammation of potassium and sodium upon water and ice, exhibited; also the regeneration of the alkali, demonstrated by the usual tests. The decomposition of potash, by iron card-teeth, heated to incandescence. Apparatus for its evolution, exhibited.

Of Potash or Potassa, and Soda, the Protoxides of Potassium and Sodium.

A ley, obtained by the lixiviation of the ashes of inland plants, especially wood, when boiled down, yields the potashes of commerce. Potashes, ignited so as to destroy vegetable colouring matter and other impurities, again solved, and boiled to dryness, form pearlash. Pearlash, dissolved in water, boiled with lime, filtered, and boiled down to the consistency of moist sugar, dissolved in alcohol, and boiled down gradually, and, lastly, fused at a red heat in a silver vessel, forms the potash, or, more strictly, the *hydrate* of potash of chemists. If, as soon as the alcohol has escaped, the residual mass be refrigerated, it crystallizes. After fusion at a red heat, the alkali contains about 20 per cent. of water, existing in it as an acid, and of which, per se, it cannot be deprived by heat.

Berzelius advises the addition of one and a half parts of pure lime, to one of the alkaline carbonate, dissolved in a cauldron, and kept boiling. The lime is not to be added at once, but gradually; as without this precaution, the resulting carbonate of lime retains, like a sponge, a great part of the alkali. The liquid is to be tested by an acid or by lime-water, until it ceases to indicate the presence of carbonic acid. After this, it may either be kept in a liquid state, or evaporated till it crystallizes, and preserved in crystals; or being ignited till it becomes fused, and poured out on a slab, or into moulds, it may be preserved in the state of hydrate. I have used for the purpose last mentioned, the moulds usually employed for casting musket balls. The spherical form, presenting the least surface in proportion to the mass, is favourable for a substance liable to be deteriorated by contact with the atmosphere. When pearlash is resorted to,—after the caustic ley has been evaporated to the consistency of moist sugar, in order to get rid of its impurities, it must be redissolved in alcohol. This liquid combines with the pure potash, while a portion of water contained in, or formed from, the alcohol, separates from it in union with the impurities. The alcohol being removed from the potash by distillation, it may be procured in the crystalline form, or in that of a dry hydrate, according to the heat employed.

According to Berzelius, pure carbonate of potash may be procured from bitartrate of potash, whether carbonized by heat, or deflagrated with pure nitre, by submitting the product to solution and vaporization.

Soda is obtained from the ashes of certain plants which grow on the sea-shore, as potash is by the incineration of those which grow inland. It is procured also from chloride of sodium, and sulphate of soda.

Soda is purified, and procured in the state of hydrate, or in crystals, by a process analogous to that above described for its kindred alkali.

Properties of Potash and Soda.—Potash and soda are of a grayish-white colour, and, in common with other alkalies, have a peculiar taste. They render tincture of turmeric brown, syrup of violets green, and alkanet blue. Colours changed by acids, are restored by them. They are the opposites of, and antidotes to, acids, and capable of forming with them neutral compounds, or, in other words, such as are neither acid nor alkaline. They are incorrectly said to render vegetable blues green, as if this were universally true. Alkanet is made blue by them, while neither litmus nor indigo is rendered green.

Although potash is more soluble than soda, and is deliquescent, while soda effloresces; yet the salts of soda are more soluble than those of potash. Both cauterize the flesh. Potash is the more active. Common caustic is an impure hydrate of this alkali.

Crystallized potash contains four atoms of water to one of the oxide, of which three only can be expelled by heat. After fusion it may be called, however paradoxical it may seem, an anhydrous hydrate, though not an anhydrous oxide. The hydrate of potash consists of one atom of alkali, and one of water.

Both potash and soda fuse when subjected to a red heat. The atomic weight of potash is 48, that of soda, 32.

Potash may be distinguished from soda, by its forming salts nearly insoluble in water with tartaric, or oxychloric acid; while those formed by soda with the same acids are soluble. Chloroplatinic acid causes a yellow, and sulphate of alumina a white, precipitate with potash, but not with soda.

249. *Experimental Illustrations.*

Characteristic changes produced in vegetable infusions, as in a previous illustration, page 254.

To saturated solutions of potash and soda, or their carbonates, a saturated solution of tartaric acid being added in excess, crystals are yielded by the potash only. Into different salts of the two alkalies in solution, chloroplatinic acid being poured, a light yellow precipitate distinguishes the potash.

Of the Peroxides and Suboxides of Potassium and Sodium.

Peroxide of potassium is produced by the combustion of potassium on a plate of silver in oxygen gas, in which case the metal acquires three times as much oxygen as it holds in the state of potash. The peroxide is also obtained when nitre is intensely heated, or when potassium is deflagrated with nitre.

Two parts of sulphate of potash, and one of lampblack, give a pyrophorus which ignites with scintillations in the air. This arises, no doubt, from the evolution of potassium, or the formation of its sulphuret.

The peroxide of potassium is of a greenish-yellow colour, and possesses most of the properties of the protoxide, excepting that of acting as a base. When brought in contact with water or acids, it is decomposed into potash and oxygen.

The peroxide of sodium is of a greenish-yellow colour also, and, in its properties, is analogous to the peroxide of potassium, except that at a high temperature it abandons part of its oxygen, and is converted into protoxide. It cannot, therefore, be obtained by burning sodium in an excess of oxygen; since the heat produced by the combustion, would decompose the peroxide, if already formed. In order to procure it, it is necessary to heat soda in contact with oxygen. The peroxide of sodium contains one and a half atoms of oxygen, united to one of metal.

Berzelius mentions that suboxide of potassium may be obtained by heating the metal in a quantity of oxygen inadequate for its saturation; also by exposing to a temperature of about 40° F., a mixture of hydrate of potash and potassium, in equivalent proportions; in which case the metal is oxidized at the expense of the combined water, the hydrogen escaping. The anhydrous protoxide may be obtained in like manner, by heating potassium with a greater quantity of the hydrate.

Turner alleges, however, that the suboxide of potassium is generally regarded by chemists as nothing more than a mixture of potassium and potash.

According to Berzelius, a suboxide of sodium may be obtained by the same means as the suboxide of potassium, substituting the one metal for the other. The same uncertainty, however, prevails with regard to it, as with regard to the suboxide of potassium.

When potassium or sodium is heated in ammonia, it combines with nitrogen and liberates hydrogen, and the resulting nitruret absorbs ammonia; so that we have a combination of two binary compounds of nitrogen, which may possess, to a small extent, the relation of acid and base. There are, however, no phenomena in chemistry which are more anomalous than those which are associated with the production and evolution of this compound. Nevertheless, as its nature is unintelligible even to adepts, I shall not present the details here.

I hinted, when entering upon the subject of nitrogen, that it would be seen in the sequel, that it was not destitute of pretensions to a place in the basacigen class. It was in reference to the phenomena above alluded to, that I made that remark.

If nitrogen form the common ingredient in two compounds, one electro-negative, the other electro-positive, which combine to form a third, it fulfils the condition of a body producing both an acid and a base, and is of course a basacigen-body. Yet it has already been pointed out that there is no class, of which some of the members do not display properties which might cause them to be placed in another class.

Of Phosphuret of Potassium.

Phosphorus and potassium, heated together in nitrogen or hydrogen gas, combine with the phenomena of combustion. In phosphuretted hydrogen, potassium burns, combining with phosphorus, and liberating the hydrogen.

This combination decomposes water, but, according to Berzelius, the gas evolved does not inflame spontaneously.

Of the Compounds of Potassium with Carbon, Boron, and Silicon.

The black matter which remains after the distillation of potassium, as obtained by Brunner's process, is alleged by Berzelius to be a *percarburet of potassium*. When moistened it inflames, no doubt by decomposing water, and evolving potassuretted hydrogen. The black matter which obstructs the tube used in the evolution of potassium by the process above mentioned, is also held to be a carburet.

These carburets I have found useful in purifying naphtha, by its distillation with them. After undergoing this ordeal, potassium may be kept in it with less appearance of reaction. I am under the impression that the carbon which remains in the iron bottle, is imbued with potassium, possibly in a state of chemical union. This may be used likewise for the purification of naphtha.

It appears as if, during the reduction of boric acid by potassium, a *boruret* is formed; since a portion of the mass evolves a gas on being moistened, which has not the smell of pure hydrogen. It is probably boruretted hydrogen.

A *siliciuret of potassium* is obtained during the decomposition of fluosilicic acid gas. A portion of the liberated silicon, combining with potassium, forms the compound in question. This, on being moistened, gives off hydrogen, which has a peculiar odour resembling that of phosphuretted hydrogen. The analogy between these results and those mentioned in reference to boron, is obvious.

SECTION III.

OF LITHIUM.

A fixed alkali was discovered, in 1818, by Mr. Arfwedson, to exist in small proportion, as an ingredient in a mineral called petalite. He afterwards discovered it in two other minerals, called spodumene and lepidolite. Allusion to this alkali, and the origin of its name, was made, page 253.

By the influence of the Voltaic pile, decided indications have been obtained of the existence, in lithia, of a metallic radical. To this the name of lithium has been given. Lithium resembles sodium in appearance. Its atomic weight is 6.

Of Lithia.

Lithia, known only in the state of hydrate, is white, caustic, and has all the attributes of an alkali. When lithia, whether in the state of carbonate or uncombined, is heated in contact with platinum, the metal is attacked, and a compound is formed, which, according to Thenard, probably consists of the oxide of platinum, united to the oxide of lithium, and must of course be a platinate of lithia. Lithia is composed of one atom of lithium, equivalent 6, and one atom of oxygen, equivalent $8 = 14$.

Lithia is less soluble in water or alcohol than soda or potash. Its carbonate is less soluble in water than the carbonates of those alkalies. The chloride of lithium is deliquescent, and soluble in alcohol, the phosphate of

Lithia is insoluble in water; in which respects these compounds differ from the corresponding combinations, formed by the other fixed alkalies, or their radicals.

Of the Reaction of Chlorine, Bromine, Iodine, Fluorine, and Cyanogen, with the Metals of the Earths and Alkalies.

In a former edition of this work, it was mentioned that for aluminium, glucinium, yttrium, thorium, and magnesium, chlorine has not sufficient affinity to expel the oxygen from their oxides; and that it was only in the state of oxide that they could be subjected to the gas. It has been already stated, that Oersted ingeniously contrived to enable chlorine to combine with aluminium, by the co-operating affinity of intermingled carbon for the oxygen with which, in the state of earth, this metal is united: also, that a similar process had been successfully employed to obtain the chlorides of glucinium, yttrium, thorium, and magnesium. The most important consideration, associated with the existence of these chlorides, is their susceptibility of decomposition by potassium, and the consequent isolation of their metallic radicals.

When the oxides of calcium, barium, strontium, potassium, sodium, and lithium are heated in chlorine, these metals are converted into chlorides, the oxygen being displaced. Potassium and sodium burn actively in chlorine, and it appears probable that any of the metals of the alkalies or alkaline earths may, with heat, if not without, be directly combined with any of the halogen bodies. The same combinations may be obtained in the wet way by complex affinity, on presenting their oxides to the acids formed by these bodies with hydrogen.

The chlorides of the metals of the alkalies, and of the alkaline earths, are all soluble, and some of them deliquescent. When in solution, they contain the same elements as if they were chlorohydrates of oxybases; and are, therefore, considered as such by some chemists.

The difference between a chloride in solution and such a chlorohydrate, is rendered evident by setting down the ingredients agreeably to both suppositions, as follows:—

$$\underbrace{\underbrace{\text{Chlorine, hydrogen.}}_{\text{Chlorohydric acid.}} \qquad\qquad \underbrace{\text{Oxygen, metal.}}_{\text{Oxide.}}}_{\text{Chlorohydrate.}}$$

$$\underbrace{\underbrace{\text{Oxygen, hydrogen.}}_{\text{Water.}} \qquad\qquad \underbrace{\text{Chlorine, metal.}}_{\text{Chloride.}}}_{\text{Dissolved Chloride.}}$$

The soluble chlorides produce precipitates in solutions of silver, lead, or black oxide of mercury. They do not deflagrate with charcoal, nor do they, like sulphates, after being heated with it, yield the odour of sulphuretted hydrogen on being moistened.

The soluble chlorides of the metals of the alkaline earths and alkalies, excepting that of magnesium, are, by heat, converted into anhydrous chlorides, easily detected by the fumes which they give with sulphuric acid.

Bromine, like chlorine, when heated with any of the fixed alkalies, or alkaline earths, except magnesia, displaces the oxygen and combines with the metallic radical. Like chlorine also, it does not, per se, produce this effect either with magnesia or the earths proper.

The affinities of iodine are, in most cases, less energetic than those of chlorine or bromine. Potash and soda are the only oxides of the metals of the earths and alkalies, from which iodine can, with the assistance of heat, expel the oxygen, in order to combine with their metals.

The bromides and iodides, when combined with water, may, like the chlorides, be regarded either as in a state of solution, or as bromohydrates and iodohydrates. The bromides may be recognised by the red vapours which arise, when they are heated in a tube with the bisulphate of potash. Similar vapours would be given out by the nitrites, if treated in the same way; but the bromides may be distinguished from those salts, by their not deflagrating when thrown on incandescent coals.

The iodides may be detected by projecting a portion into a tube containing a small quantity of sulphuric acid.

By these means iodine, if present, will be made apparent in the form of a violet vapour. Iodine is also displaced from its combinations by chlorine; and, when these, previously to the addition of chlorine, are mingled with a paste made of starch, a blue colour is produced. It is alleged that sea salt sometimes contains a quantity of iodine adequate to produce this result.

Berzelius states that, when potassium is heated in cyanogen, it is converted into a cyanide; also that the habitudes of sodium are in this respect similar. It is probable that the same result would ensue with all the metals of the alkalies and alkaline earths. Cyanogen is usually generated by the reaction of potash with animal matter, which deoxidizes the alkali, and at the same time furnishes to it the elements of cyanogen, which, in consequence, simultaneously unite with each other and with the metal, forming a cyanide of potassium.

When the cyanoferrite of potassium (ferroprussiate of potash) is intensely heated, the cyanoferric acid is decomposed. The cyanide of potassium remains mingled with a carburet of iron, and may be extricated by solution, filtration, evaporation, and crystallization. Subjecting the cyanoferrite of sodium to a similar process, the cyanide of sodium may be obtained. (See page 293.)

The cyanides may be detected by their power of producing a blue colour with solutions of the peroxide of iron; also by evolving the odour of peach blossoms, when subjected to chlorohydric acid.

Could fluorine be isolated, it is highly probable that its reaction with the metals of the earths and alkalies would be analogous to that of chlorine. The fluorides, however, differ much from the chlorides in solubility. Some varieties of the fluoride of calcium constitute Derbyshire spar, while the chloride of calcium is a deliquescent salt.

The presence of fluorine in a mineral may, in a majority of instances, be detected by the following process. Let a small portion of it be pulverized, and subjected to heat with about twice its weight of concentrated sulphuric acid, in a leaden, silver, or platinum cup. Let this cup be covered by a glass plate, coated with beeswax, through which some letters have been traced so as to denude the vitreous surface. After exposure for half an hour, aided by as much heat as can be used without melting the wax, the glass should be relieved from its coating and examined. Then, if the portions of the vitreous surface, exposed to the fumes, prove to be so corroded as to render the characters traced through the wax distinguishable, the presence of fluorine may be inferred.

Berzelius informs us that when this principle is in combination with silicon, it will not act on glass. Hence he advises that the mineral, suspected of containing fluosilicic acid, should be subjected to the flame of the blowpipe, at one end of a glass tube, of which both ends are open; so that the fumes produced may be impelled by the blast through the tube from one orifice towards the other. By these means, milky spots will appear on the glass, in consequence of the condensation of water containing fluosilicic acid, if this be an ingredient in the mineral.

Of the Reaction of Sulphur, Selenium, and Tellurium, with the Metals of the Earths and Alkalies.

Sulphur unites with all the metals of the alkalies and alkaline earths, so far as the experiment has been tried, whether presented to them in the metallic state, or in that of oxide. Its power of reducing their oxides is greater than that of any other basacigen body; as when present in excess, it acts by its affinity for the oxygen and the metal. (See 4th case of affinity, page 136.) The affinity of the halogen bodies for oxygen, is so inferior to that of sulphur, that when oxygen is expelled from oxides by one portion of them, it does not combine with another, however great the excess in which they may be present.

Sulphides (sulphurets) are also formed by deoxidizing the sulphates by carbon or hydrogen with the aid of heat; by boiling sulphur in water with the earth or alkali to be converted; or by passing sulphydric acid into water, holding the oxide in solution or suspension. When this is done under favourable circumstances, the metal is converted into a sulphobase by the sulphur of one portion of the acid; while the compound thus formed unites with another portion of the acid, forming a sulphosalt, denominated a *sulphydrate*. This view of the subject we owe to Berzelius, who has shown that sulphur, selenium, and tellurium all have the property of forming acids with one set of radicals, and bases with another; and that the sulphacids and sulphobases thus formed, are capable, like ox-

and oxybases, of forming compounds which he con- s as sulphosalts, or salts in which sulphur performs rt analogous to that which oxygen performs in oxy- such as the sulphate or nitrate of potash.

rmerly it was supposed that, when absorbed by an ne solution, sulphydric acid (sulphuretted hydrogen) ined with the oxybase, forming what was called a sulphuret. It was also supposed that a sulphide of kalifiable metal, by solution in water, would be con- d into an oxybase by the oxygen of the water; while ydrogen, with a double proportion of sulphur, form- isulphuretted hydrogen, would combine with the oxy-

rough the sagacity and industry of Berzelius, much ledge has of late years been acquired respecting the inations of sulphur with the alkaline metals. He ions seven compounds, in which, supposing the quan- f the potassium in each to be the same, the quanti- f the sulphur are severally 1, 2, 3, 3½, 4, 4½, 5.

remember the details respecting the preparation and cteristics of these sulphides, would be too great a en for the memory of those who are not so situated take a particular interest in them.

lphides of the metals of the earths and alkalies, on moistened with water, evolve sulphydric acid, and ice this result still more actively on being subjected lorohydric acid.

e selenides of the metals of the earths and alkalies in most cases, be produced by heating the metal selenium. The selenides of these metals bear a great nblance to the sulphides, and when heated are re- l to the metallic state, producing the smell of horse- h.

e tellurides are but little known, and, except so far ey act as telluracids or telluribases, unimportant.

250. *Experimental Illustrations.*

lphides in solution exhibited. Earths precipitated by .

OF METALS PROPER.

The metals included under this head, are *gold*, *platinum*, *silver*, *mercury*, *copper*, *lead*, *tin*, *bismuth*, *iron*, *zinc*, *arsenic*, *antimony*, *palladium*, *rhodium*, *iridium*, *osmium*, *nickel*, *cadmium*, *chromium*, *cobalt*, *columbium*, *manganese*, *molybdenum*, *titanium*, *tungsten*, *uranium*, *cerium*, and *vanadium*.

SECTION I.

OF GOLD.

Gold is usually found in nature nearly pure. It is not liable, like other metals, to be disguised by a union with oxygen or sulphur. The precipitate obtained from a solution of gold coin in aqua regia, by the green sulphate of iron, is pure gold. This metal is also purified by exposure to heat and air, or by nitric acid, by which means baser metals are oxidized; as in the processes of cupellation and parting.

From the sands, or ores, in which they exist naturally, minute portions of gold are collected by trituration with mercury, with which they amalgamate. The gold, thus secured, is separated from the mercury by distillation.

Properties.—Its colour and lustre are well known. Its specific gravity is 19.3. It is the most malleable and ductile metal, and suffers the least by exposure to air and moisture. Gold leaf, which is about 1000 times thinner than printing paper, retains its lustre in the air. Gold leaf transmits a greenish light, but it is questionable whether it be truly translucent. Placed on glass, and viewed by transmitted light, it appears like a retina. It is erroneously spoken of as a continuous superficies.

Gold fuses at a low white heat, but requires the temperature produced by the compound blowpipe, by galvanism, or by the explosive power of electricity, to volatilize or oxidize it. Its not being liable to tarnish by exposure, is due to the weakness of its affinity for oxygen or sulphur.

When a solution of chloride of gold is mixed with sulphuric ether, the ether takes the metal from the chlorine retaining it in solution. If iron or steel be moistened this ethereal liquid, it is productive of a slight gild-

osphorus, carbon, and the baser metals, also hydro- as and its compounds, by attraction for oxygen, pre- te gold in the metallic form.

ith arsenic, gold combines energetically, absorbing etal in the form of vapour, at a red heat, without ging colour. Gold loses its malleability by acquiring of its weight of arsenic.

obably gold may be united with all the metals. It gamates readily with mercury. Phosphorus forms a e compound with gold. The equivalent of gold is

Of the Compounds of Gold with Oxygen.

ording to the nomenclature employed by Thenard, an oxide, con- of one atom of the radical and two of oxygen, is a *bioxide*. In a *e*, agreeably to the same authority, there are, as the word implies, toms of oxygen to one of the radical. I prefer these appellations e of *deutoxide* or *tritoxide*, where the proportions are as above They are more precise and descriptive. These names differ in eaning from the others above cited, which merely convey the idea e oxide belongs to the second or third stage of oxidation, whether portions be 1 to 2, or 1 to 3, or 1 to $1\frac{1}{2}$, or 2 to 5.

ubjecting a protochloride of gold to a solution of caustic potash, oxy- kes the place of the chlorine, and protoxide of gold results. A part remains in solution, and is converted into a trioxide and metallic The trioxide of gold is obtained by digesting an aqueous solution bichloride with magnesia in slight excess. This oxide, which is e of acting both as an oxacid and as an oxybase, in this instance in the former capacity, combines with the magnesia, and constitutes ate, of which the greater part precipitates, while the remainder con- n solution. The precipitate should be washed with water until it to acquire a yellow colour by the addition of chlorohydric acid. It then be digested with nitric acid, which combines with the magne- d thus isolates the trioxide. If the nitric acid employed be concen- we obtain the trioxide in an anhydrous state, and of a brown colour; lilute, as a yellowish-red hydrate.

protoxide consists of one atom of gold and one of oxygen, the tri- of one of gold and three of oxygen. Hence, agreeably to the ex- of Thenard, I designate it as a *tri*oxide. Acting as a base, this ombines with nitric or sulphuric acid. It is precipitated from these ations by water, which acts, probably, in this case, as an oxybase rogen.

n oxacid, trioxide of gold unites with all the alkalies and alkaline The aurate of ammonia, a compound which explodes by percus- as long been known under the name of fulminating gold. Berze- eges that there are two kinds; one, containing an excess of am- detonates more powerfully; the other, formed with a lesser quan- he alkali, contains chloride of gold, by which its power is enfeebled.

A precipitate, of a beautiful purple colour, may be obtained either by mixing diluted solutions of the chlorides of tin and gold; or by immersing an ingot of tin, or tin foil, in a solution of chloride of gold, containing some free chlorohydric acid. To this precipitate the name of purple powder of Cassius has been given. I infer from the account of this compound, given by Berzelius, that it consists of gold, tin, hydrogen, and oxygen. Respecting the mode of combination there is some obscurity.

In consequence of this property of producing the purple of Cassius, tin, whether in the metallic state or that of dissolved protochloride, is the best test for gold.

Berzelius does not consider the purple powder into which gold is reduced by successive electric discharges, as any thing more than metallic gold in a state of minute division.

Of the Compounds of Gold with the Halogen Class.

Chlorine exercises a very energetic affinity for gold. A combination between them ensues, whether the metal be heated in the gas, or presented to it in aqueous solution, or in aqua regia. The liquid which bears this name, is produced by the mixture of chlorohydric with nitric acid. It ought not, however, to be considered as a combination of them. As soon as the mixture is effected, a decomposition of both of the acids commences. All the hydrogen of the one, and part of the oxygen of the other, unite to form water; chlorine and nitrous acid being disengaged and more or less evolved, especially if aided by heat. Excepting that it contains chlorine in a higher degree of concentration, which of course enables it to act with more energy, aqua regia does not differ, ***in its solvent powers***, from a solution of chlorine in water. It cannot properly be considered as a distinct acid; since it only acts by imparting chlorine, being incapable, as an aggregate, of entering into composition.

The name of aqua regia, or royal water, was given to this solvent, on account of its property of dissolving gold, the alleged king of metals. Since the promulgation of the French nomenclature, it has been called nitro-muriatic acid; but as this conveys a false idea of its nature, I would call it by its old name, aqua regia, or, if a new name be necessary, I would suggest that of nitrohydrous chlorine. Formerly the aqueous solution of chlorine and aqua regia were the only known solvents of gold. Latterly Gay-Lussac has alleged that iodic acid is a solvent of this metal; and by Mitscherlich, the same power is ascribed to selenic acid.

The protochloride of gold is obtained by exposing the trichloride to a gentle heat, which drives off two atoms of chlorine, leaving the gold in combination with the remainder. If the heat be carried too far, it is apt to decompose the protochloride into metallic gold and chlorine. On this account it is better to stop the operation before the trichloride is entirely decomposed, and to wash the resulting mass with water, which removes the trichloride, and leaves the protochloride, which is insoluble in that fluid when cold. A solution of the chlorohydrate of the trichloride of gold, the trichloride acting as a chloribase, is obtained when gold is dissolved in aqua regia.

The trichloride may be isolated by heat, which expels the chlorohydric acid. It is of a pale yellow colour, and has an astringent and disagreeable taste. This chloride combines as an acid with the chlorides of the alkaline metals, forming chloroaurates. Hence I consider this as entitled to the appellation of chloroauric acid. The trichloride of gold, is composed of one atom of gold, and three atoms of chlorine.

Bromine forms with gold a tribromide, which corresponds in composition and chemical properties with the trichloride of the same metal.

The iodide of gold agrees, in composition and chemical relations, with the protochloride of gold.

The cyanide of gold appears to act as an acid.

Of the Nomenclature of the Chlorides of Gold.

In designating the trichloride of gold by the name of chloroauric acid, and in speaking of its combination with the chlorides of potassium and sodium, &c. as chloroaurates, I find I am supported by the opinion of Thenard, who, in the second and third volumes of the new edition of his work, wherever he has occasion to mention the combination of the electro-negative with the electro-positive chlorides, speaks of the electro-negative compound as playing the part of an acid. Moreover, in the third volume of his work, in treating of compounds, consisting severally of two sulphides, two selenides, or two tellurides, he expresses the opinion that it would be inconsistent to designate these as combinations of sulphacids and sulphobases, &c., if analogous terms are not to be applied to the electro-negative and electro-positive ingredients in the double haloid salts of the Berzelian nomenclature.

Dumas, in his Traité de Chimie, in describing the combinations formed by electro-negative with electro-positive chlorides, represents the former as acting the part of chloracids, the latter of chlorobases.

Dr. Thomson has adopted views corresponding, in this respect, with those of Thenard and myself, and actually employs, to a great extent, the same language.

Of the Compounds of Gold with Sulphur.

Gold forms with sulphur a protosulphide and a trisulphide. The protosulphide is formed by passing a current of sulphydric acid gas through a boiling solution of the trichloride. It is of a deep brown colour, and is decomposed by heat into metallic gold and sulphur.

The trisulphide may be precipitated by passing a current of sulphydric acid into a dilute solution of the trichloride, or by adding an acid to a solution of the sulphaurate of potassium. The trisulphide is of a deep yellow colour, and is decomposed by heat. With sulphobases it acts as an acid, but with the more powerful sulphacids as a base.

251. *Experimental Illustrations.*

Some gold leaf is placed in two glass vessels. Nitric acid being poured into one, and chlorohydric acid into the other, the gold is not acted upon; but when the contents of the two vessels are united, the gold disappears.

Gold, dissolved by aqua regia, and precipitated by sulphate of iron, or by chloride of tin. A cylinder of phosphorus, immersed in a solution of the metal, acquires the appearance of a cylinder of gold. Separation of gold from its solution by ether. Effects of the ethereal solution exhibited. Action of mercury on gold leaf.

SECTION II.

OF PLATINUM.

This metal, in the crude state of its native grains, as it comes from South America, may be dissolved in aqua regia, by which it is converted into chloroplatinic acid.* A solution of sal ammoniac being added, an orange-coloured precipitate results of chloroplatinate of ammonium. Ignition developes the metal from this precipitate, but in a divided state. By intense pressure, the minute particles, thus procured, are made to cohere, so far as to sustain the welding process. By this they are made to coalesce into a perfectly solid and coherent mass.

According to Berzelius, platinum, as obtained by the process above mentioned, is alloyed with iridium, and inferior to the pure metal in colour, brilliancy, ductility, and malleability; while at the same time it is stronger and more suitable for the purposes for which it is usually employed. It may be obtained pure, by precipitating chloroplatinic acid from its aqueous solution by chloride of potassium, igniting the precipitate, redissolving it, and precipitating again by sal ammoniac; and lastly, by reducing the precipitate by ignition to the spongy form, from which, by pressure and the welding process, it may be made coherent and malleable, as in the above mentioned process for obtaining the metal.

Properties.—The colour of this metal as ordinarily obtained, is intermediate between that of silver and steel; but when pure, as above stated, it resembles silver in colour and softness, more than when alloyed with iridium. Its specific gravity is 21.53. A cubic inch of it weighs nearly three-fourths of a pound. It is about twice as heavy as lead, being the heaviest body known. It is less ductile and malleable than gold, but harder and more tenacious; though, in these respects, inferior to iron. Like iron, it is susceptible of being hammered and welded at a white heat. It can neither be oxidized nor melted by the highest temperatures of the air furnace or forge. It was first fused in a focus of the solar rays, afterwards by means of a stream of oxygen gas on ignited charcoal, but much more easily by the compound blowpipe, under which it was first oxidized and dissipated by heat. It fuses and burns easily in the Voltaic circuit, and is dispersed and oxidized by mechanical electricity. It is one of the worst conductors of heat among metals.

---

* See Letter on the Berzelian Nomenclature, in the Appendix.

In its habitudes with oxygen, chlorine, and the acids, it is analogous to gold, being, like that metal, detected by protochloride of tin, which produces with it a claret colour. It unites so energetically with tin at a red heat, as to occasion the phenomena of combustion. When in a divided state, as obtained by igniting the chloroplatinate of ammonium, it amalgamates with mercury by trituration.

Platinum combines with boron, silicon, and phosphorus. On account of its infusibility at the highest temperatures produced by the air-furnace, or forge, and its insusceptibility of being corroded by the acids usually employed in chemical processes, it is much used by chemists for crucibles, evaporating vessels, and spoons; also in experiments in which Voltaic series are resorted to as a means of decomposition. I employ it in my galvano-ignition apparatus (see page 107). At high temperatures, it is acted upon by the alkaline hydrates, and by almost all metals, especially tin and lead. I had a platinum crucible perforated, by fusing in it some flint glass, which consists of lead, silicic acid, and potash.

The equivalent of platinum is 99.

Of the Compounds of Platinum with Oxygen.

Platinum forms a protoxide, consisting of one atom of metal and one atom of oxygen, which may be obtained from the chloride, by the addition of potash. It forms also a bioxide, containing two atoms of oxygen to one of metal, as the name implies. The protoxide acts as an oxybase only; the bioxide, both as an oxybase and oxacid. In the last mentioned capacity it enters into combination with ammonia, in the compound called fulminating platinum, and which we may with propriety call platinate of ammonia, or ammonium. Dr. Thomson alleges the existence of some other oxides of platinum.

Of the Compounds of Platinum with the Halogen Class.

Platinum forms two compounds with chlorine. The protochloride consists of one atom of platinum and one of chlorine; the bichloride, of one atom of platinum and two of chlorine.

The protochloride of platinum is obtained by subjecting the bichloride to heat. If the heat be pushed too far, the protochloride is decomposed. This chloride, according to Thenard, combines as a base with chlorohydric acid. As an acid, it unites with the chlorobases. I would therefore call it *chloroplatinous acid*, and the salts which it forms, chloroplatinites. Chloroplatinous acid is of a grayish colour, and insoluble in water.

The bichloride of platinum may be procured by evaporating a solution of platinum in aqua regia, which yields crystals of the chlorohydrate of the bichloride of platinum, from which the chlorohydric acid may be driven off by a gentle heat. In colour it is dark reddish-brown, and in taste, disagreeable and astringent. It dissolves in water, forming a solution which, when saturated, is of a deep red colour. It combines with a great number of other chlorides, with which it acts the part of an acid, although it is susceptible of uniting with chlorohydric acid as a base. Its properties in these respects entitle it to the appellation of *chloroplatinic acid.*”

Bromine forms with platinum, a compound analogous in composition to the bichloride of that metal, and which, from its chemical properties, is entitled to the appellation of *bromoplatinic acid.*

Iodine and fluorine both form compounds with platinum. The fluoride of platinum acts as an acid; the properties of the iodide in this respect are unknown.

Cyanogen forms two compounds with platinum. The percyanide combines with cyanobases as an acid, and of course may be designated as *cyanoplatinic acid.*

Of the Compounds of Platinum with Sulphur.

Platinum combines with sulphur in two proportions. Both sulphides combine as sulphobases with sulphacids, but the persulphide unites as a sulphacid with sulphobases of the alkalifiable metals.

252. *Experimental Illustrations.*

Platinum exhibited in the state of native grains, and in the malleable state. Precipitated from its solution by chloride of ammonium, and chloride of tin. A precipitate produced in salts of potash by chloride of platinum, distinguishes them from salts of soda. Combustion of platinum with tinfoil.

Of the Power of Platinum, and other Metals in a divided or spongy Form, to induce Chemical Reaction.

In the spongy form in which platinum remains after the chlorine and onia of the chloroplatinate are expelled, it has the wonderful power of causing the inflammation of a mixture of hydrogen and oxygen gas. I have ascertained that this power is acquired by asbestos, porcelain earth, and charcoal, merely by soaking them in a solution of chloride of platinum, and subsequent desiccation and ignition. Thenard states, that platinum filings, platinum leaf, or an association of fine platinum wires, exercise, in a greater or less degree, the same power as platinum sponge.

The pulverulent mass, obtained by precipitating platinum by zinc, becomes incandescent in the vapour of alcohol. As the best means of obtaining platinum in that state of minute division in which it is most efficacious in producing this result, Liebig recommends that the chloride should be dissolved in a lixivium of caustic potash with heat; and that while the resulting liquid is still hot, alcohol should be added in small quantities, stirring the mixture until an effervescence arises from the extrication of carbonic acid. This, however, becomes so active as to render a very capacious vessel necessary for the process. The platinum precipitates in the form of a black powder, which is to be separated from the liquid, and washed successively with alcohol, with a solution of potash, with chlorohydric acid, and four or five times with water. When dried, the powder resembles lampblack, and soils the fingers. Nevertheless, it consists only of platinum in a state of minute division, since it may be heated to a cherry-red in the air or in oxygen, without losing weight or undergoing any change in its properties. These are, however, destroyed by incandescence, which restores its metallic appearance. Under the burnisher, it becomes slightly of a metallic gray. In aqua regia, it dissolves without leaving any residue.

Its properties are as follows: like charcoal, it condenses the gases in its pores, with a development of heat; and if, after being deprived of air and moisture by exposure to a vacuum over sulphuric acid, the atmosphere be rapidly admitted, it becomes red-hot. It causes the combustion of hydrogen or alcoholic vapour, when in contact with them with access of air, and becomes incandescent on falling on a surface wet with alcohol. If moistened with alcohol, it converts it, at the expense of the oxygen of the air, into acetic acid and acetic ether. Platinum, however prepared, gradually loses the property of causing a union between oxygen and hydrogen; but this property disappears much more rapidly when exposed to the action of the air, than when protected from its influence. Spongy platinum, moreover, which from its structure does not readily admit air into its pores, remains effective longer than platinum under any other state; unless that in which it is procured by precipitation by zinc be an exception. Platinum leaf, which in the air is rendered powerless in a few minutes, when in the form of a scroll and included in a close vessel, remains effective for twenty-four hours. The power of producing a union between hydrogen and oxygen, may be restored by immersion in an acid, or by incandescence.

Platinum is not the only substance which possesses the property of producing the combination of oxygen and hydrogen. Gold, precipitated from its solution by means of zinc and subsequently heated to redness, if assisted by a temperature of 122°, causes the union of hydrogen and oxygen. Osmium slowly produces the same effect, at a heat a little below that which is necessary in the case of gold. Spongy nickel acts slowly at the ordinary temperature of the atmosphere. Palladium, rhodium, and iridium produce the same effect on a mixture of hydrogen and oxygen as platinum, though with less intensity. Charcoal, porcelain, glass, and rock crystal produce a union between hydrogen and oxygen, at temperatures lower than that at which it would otherwise take place.

253. *Experimental Illustrations.*

A mixture of hydrogen and oxygen inflamed by platinum sponge, or platinated asbestos. Incandescence of platinum powder produced by moistening it with alcohol.

SECTION III.

OF SILVER.

Silver exists in nature nearly pure, but usually containing a minute quantity of gold, copper, arsenic, or iron. It also exists in alloys, containing various equivalent proportions of arsenic, antimony, tellurium, or gold. It is found, likewise, in the state of chloride, iodide, sulphide, and carbonate, and in a variety of galena, the native sulphide of lead, called, in consequence, argentiferous galena. In consequence of its fusibility and insusceptibility of oxidizement,–when any metallic alloy, containing it, is exposed to intense ignition with access of air, the silver is separated from any metal which, when thus exposed, is liable to be converted into an oxide. In the small way, this object is effected upon the *cupel*, in the operation called cupellation. A cupel is a small flat cylinder, made of bone earth obtained by calcination, in the upper surface of which there is a hemispherical cavity. In this cavity any gold or silver to be refined is placed with a portion of lead. The cupel is then placed in a small earthenware oven, called a muffle, and exposed to a heat sufficient to render and keep the metals fluid. Under these circumstances, the lead is oxidized and vitrified, and promotes a similar change in any other metals present, which are susceptible of oxidizement under the circumstances in question. The vitreous matter, thus produced, is absorbed by the bone earth. After the process has endured sufficiently, only the gold and silver, or other noble metals should any be present, can remain upon the cupel. This stage of the process is indicated by the metallic surface being no longer obscured by any film of oxidized matter.

As in the cases in which this process is employed, no other noble metals are liable to be present besides gold and silver, I shall treat of it only in reference to them.

From the alloy purified upon the cupel, the silver may be removed by nitric acid, when the gold does not exceed a fourth of the whole. In order, therefore, to enable the nitric acid to dissolve the silver, the mass is fused with the addition of as much of this metal, as will establish the requisite ratio between it and the gold. This is called *quartation*. The process of separating the metals afterwards by nitric acid, is called *parting*.

If the alloy be subjected to aqua regia, the gold only will be taken up. The silver will precipitate as a chloride, and the parting will be effected the easier, in proportion as the quantity present of the last mentioned metal is less.

Silver, contained in argentiferous copper, is extracted by means of lead, in the process called liquation. The alloy is fused with two and a half parts of the metal last mentioned, and cast into thick round cakes. These are subsequently exposed in a reverberating furnace, to a heat sufficient to melt the silver and lead, leaving the copper, which has scarcely any affinity for lead. The silver is afterwards separated from the lead by cupellation.

Pure silver may be obtained from silver coin by various means. The white crystals spontaneously afforded by a solution of the coin in nitric acid, cautiously drained, and washed with a portion of water barely sufficient to remove every vestige of green, yield a solution of pure silver. The residual liquid may be decomposed by copper, and the precipitate redissolved, and crystallized by evaporation; and thus a fresh crop of white crystals may be procured. The whiteness of the crystals may be deemed the criterion of their purity. Silver precipitated by mercury, as in the case of the arbor Dianæ, only requires ignition to render it pure.

Properties.—Excepting steel, silver is susceptible of the highest degree of metallic brilliancy; and next to gold, it is the most malleable and ductile metal. In metallic whiteness it is pre-eminently beautiful, and in tenacity inferior only to iron, copper, and platinum. Its specific gravity is 10.5. It is the best conductor of caloric, fuses at a low white heat, is as difficult to oxidize in the fire as gold, but is more liable to tarnish when exposed to the atmosphere, from its susceptibility to the action of sulphur and chlorine. Hence it is blackened by eggs and by salt water.

By the compound blowpipe, electricity, or galvanism, silver is fused, oxidized, and dissipated. Its equivalent is 108.

Exposed to nitric acid, it is oxidized by one portion, and dissolved by the other. In fact this acid is its proper solvent. The resulting nitrate, when fused and cast into sticks, forms the lunar caustic of the shops. It consists of one atom of acid 54, and one of oxide 116, = 170.

Sulphuric acid, when cold, has no reaction with silver. At a boiling heat, the metal is oxidized at the expense of one portion of the acid; and the oxide, thus formed, is dissolved by another portion, as in the case of nitric acid.

Silver combines with phosphorus, and in minute proportion with carbon and silicon.

Of the Compounds of Silver with Oxygen.

Silver forms two oxides. The protoxide is obtained by decomposing the nitrate by potash or soda. It is of a deep olive colour, slightly soluble in water, and, according to Thenard, sufficiently alkaline to render syrup of violets green. It revives simply by the influence of heat, and of course is reducible when heated with those radicals, which, under the same circumstances, combine, per se,* with oxygen. When thus reduced, it must of course produce the vivid ignition which is consequent to the presence of pure oxygen.

This oxide, by uniting with ammonia, produces a fulminating compound, so dangerous that few persons have been willing to encounter the risk of making it. This should not be confounded with the fulminate of silver, consisting of the same metal and fulminic acid, treated of at page 295.

The peroxide of silver is formed around the wire, proceeding from the positive pole of the Voltaic series, when a weak solution of nitrate of silver is placed in the circuit. It crystallizes in long needles, endowed with a metallic brilliancy. It does not combine with acids, but when presented to them, by a partial relinquishment of oxygen passes to the state of protoxide. This oxide does not act either as a base or an acid. It detonates with phosphorus, if struck with a hammer while in contact with that substance; and when subjected to ammonia, disengages nitrogen from it by oxidizing the hydrogen.

---

* These words have long been used by chemists to convey the idea of changes sustained in a mass apparently isolated, or not subjected to the influence of any other ponderable matter.

The protoxide of silver consists of one atom of silver, equivalent 108, and one of oxygen, equivalent 8 = 116.

Some chemists suppose the existence of a suboxide of silver.

Of the Compounds of Silver with the Halogen Class.

Silver unites with chlorine when heated in it, or presented to it in solution. The resulting chloride is one of the most insoluble combinations. Hence, silver is not soluble in aqua regia, or any other liquid containing chlorine; and on this account, soluble chlorides yield a precipitate, when solutions of silver are added to them.

The chloride of silver is white and tasteless, and, according to Thenard, when exposed to light, is decomposed, forming a subchloride. It combines as a base with the electro-negative, and as an acid with the electro-positive chlorides.

It is susceptible of fusion without decomposition, forming what was called by the old chemists, luna cornea, or horn silver.

Chloride of silver is soluble in liquid ammonia, forming chloroargentate of ammonium. It may be decomposed by hydrogen, if brought into contact with this gas in its nascent state, as when evolved from zinc or iron by a diluted acid. It is easily decomposed by the compound blowpipe, supplied with hydrogen and atmospheric air; also by fusion with the fixed alkalies, or when boiled in water with shreds of iron. The formation and subsequent decomposition of the chloride, is one of the modes of obtaining pure silver.

The chloride of silver is composed of one atom of silver, and one atom of chlorine.

Bromine and iodine form, with silver, compounds analogous in composition to the chloride. The bromide and iodide, acting as acids, combine with the bromides and iodides of the alkalifiable metals, acting as bases. A native iodide of silver has been found in Mexico.

Fluorine and cyanogen both combine with silver; the fluoride acts as a base, the cyanide as an acid.

Of the Compound of Silver with Sulphur.

The sulphide of silver is solid, ductile, easy to cut, of a lead-gray colour with a metallic brilliancy, more fusible than silver, crystallizable in cubes or octohedra, and indecomposable by fire. It acts as a powerful sulphobase.

This sulphide is produced whenever silver is exposed to sulphur, or sulphydric acid. The blackening of silver spoons by eggs, is ascribed to the existence of a minute portion of sulphur in the albumen. The impression has been entertained that persons, who use the water of the white sulphur springs freely, find silver coin, carried about them, blackened by the sulphur introduced into the blood. This, however, may arise from their frequenting the spring, and thus exposing the silver about their persons to the action of the sulphydric acid gas which is continually evolved from the water. I am, however, far from deeming the fact improbable. It would, a priori, be no more surprising that the animal frame should be imbued with sulphur than with mercury.

254. *Experimental Illustrations.*

Exhibition of an assay furnace and muffle: also of a cupel. Oxidizement and solution of silver in nitric acid exemplified: also its precipitation by chlorides, phosphates, arsenites, arseniates, copper, and mercury.

* * *

SECTION IV.

OF MERCURY.

This well known metal is found in nature in the metallic state, pure, and amalgamated with silver; also in the states of sulphide and of chloride. It is obtained principally from cinnabar, the native sulphide, and the most abundant and prolific of its ores, by distillation with the hydrate of lime. In this country it may always be procured nearly pure, in the iron bottles in which it is imported. It is alleged that mercury may be purified by distillation with iron filings. I once distilled several hundred pounds in this way for my mercurial reservoir, but did not find it to be quite pure afterwards. A better mode is to leave it exposed to dilute sulphuric acid in a porcelain dish, for a month or more. Under these circumstances, any metal having a greater affinity for oxygen than mercury, will be taken up by the acid. When pure, it may be shaken in a white porcelain cup without soiling the surface.

Mercury may be much improved in purity, simply by agitation; as, for instance, by shaking it in a bottle, allowing it to fall from a great height, or attaching a vessel containing it to some part of a machine in motion.

Properties.—Mercury is the only metal which is liquid at the ordinary temperature of the atmosphere. In colour and brilliancy it resembles and rivals silver. It freezes into a malleable solid at —39°, and boils at 600°. At the temperature of 60°, its specific gravity is 13.6; but in freezing, it is increased to 14.4. From some experiments of Faraday, it would appear that mercury vaporizes to a minute extent, whenever the temperature of the air is above 70°.

:urial compounds are all volatilizable by heat; and ial salts, when moistened, and rubbed upon copper, : with a film of mercury.

alleged that, if a drop of any liquid containing y be placed upon gold, and touched with the blade ife, or a piece of iron wire, the mercury will be ated upon the gold.

equivalents of mercury, and of its compounds ygen, chlorine, and sulphur, are as follows:—

y,	-	-	-	equivalent	202
de,	1	atom mercury	with	1 atom oxygen	210
,	1	„	„	2 atoms „	218
loride,	1	„	„	1 atom chlorine	238
ide,	1	„	„	2 atoms „	274
lphide,	1	„	„	1 atom sulphur	218
ide,	1	„	„	2 atoms „	234

Of the Compounds of Mercury with Oxygen.

e is still some discordancy in the opinions and lan- of chemists respecting the oxides of mercury. It n generally held that there are two oxides of this one black, the other red. According to the table valents in the Appendix, the atom of mercury with one atom of oxygen, forms the black oxide or de, = 210, and with two atoms of oxygen forms oxide, peroxide, deutoxide, or bioxide, = 218. Dr. on, conceiving the atom of mercury to have only e weight here assigned to it, considers the black s consisting of two atoms of metal, and one of oxy- d consequently designates it as a suboxide. The ce in this case, therefore, is only hypothetical. ibourt has advanced that there is only one oxide of y, the black oxide being composed, according to the red oxide and metallic mercury. Donovan, on er hand, has shown that, when a small quantity of is added to a comparatively large quantity of a pure protoxide or suboxide is obtained.

protoxide of mercury may be obtained by digest- protochloride with an excess of potash. The and chlorine exchange places, and the chloride of m, and protoxide of mercury are formed. This ay be precipitated from a solution of the ni

)

of the protoxide, by the addition of an alkaline solution. It has likewise been supposed to be produced when mercury is subjected to long continued agitation, in contact with air. It is, however, alleged by Berzelius, that the black powder, thus obtained, is metallic mercury in a state of extreme division, to which it could not be reduced without the interposition of the oxide, resulting from the presence of a more oxidizable metal; that, when the metal is quite pure, and free from the interposition of heterogeneous particles, it undergoes no change by agitation; but that if, under the same circumstances, it be triturated with grease, gum, powdered glass, or sand, it may be reduced to a black metallic powder. He conceives that all the preparations made by triturating mercury with grease, gum, or other viscid substances, contain the metal in a divided state, but not oxidized.

The protoxide of mercury is a black powder, which, by exposure to light, or to the heat of boiling water, is converted into metallic mercury and bioxide.

The *bioxide* may be procured by long exposure of mercury to a heat sufficient to cause a gentle ebullition, the air having free access. It may likewise be obtained by expelling the acid from the nitrate by heat. Berzelius informs us, that, agreeaby to the opinion of some respectable physicians, it is only when procured by the former method that it is fit to be used internally. He attributes this difference to the fact of its sometimes retaining, when obtained from the nitrate, a small portion of nitric acid. This oxide, when in mass, is of a beautiful red colour, but, when powdered, assumes a yellowish appearance. It is decomposed into metallic mercury and oxygen at a heat a little below redness. In water it is slightly soluble, and its solution has the property of rendering syrup of violets green.

Both the oxides of mercury act as bases. The bioxide forms with ammonia a fulminating compound.

Of the Reaction of Acids with Mercury and its Oxides.

When nitric acid, whether cold or hot, concentrated or dilute, is brought into contact with mercury, one portion of the acid is decomposed, imparting oxygen to the metal; the oxide thus formed being dissolved by the remainder of the acid. When the metal is in excess, the protoxide is principally formed. When the acid is in excess, the bioxide predominates. Usually, more or less of each oxide is formed.

Whether concentrated or dilute, cold sulphuric acid does not react with mercury; but when the concentrated acid is boiled on the metal, the phenomena are analogous to those which ensue in the case of nitric acid. One portion of the acid yields oxygen to the metal; another combines with the oxide thus created.

As in the case of nitric acid, we may have the oxybase of mercury in the state of bioxide, or of protoxide, accordingly as the acid or the metal is in excess, or as the time allowed for oxidizement is greater or less.

Each oxide of mercury forms three salts with nitric acid. When washed with hot water, the bisulphate of the bioxide yields a yellow compound known under the name of *turpeth mineral.* It is a subsulphate, consisting of four atoms of oxide and three of acid.

Although in the metallic state, mercury has generally no reaction with acids; yet in the state of an oxide, it is no doubt liable to be combined with any of them. About one hundred mercurial salts are mentioned in Thomson's Inorganic Chemistry. With these compounds, without a special motive, it would be worse than useless for a medical student to burthen his memory. But it is fortunate that, in this branch of our knowledge, we are aided by analogy, and that we are enabled, when we hear of an oxacid, to infer that the formation of a corresponding salt with each oxide of mercury is possible. Moreover, agreeably to the received principles of chemical nomenclature, we are enabled to assign to the compound thus imagined, a name which would be recognised by another chemist.

In the metallic state, mercury has no reaction with acids, having hydrogen for their radical, called hydracids* by some chemists. Yet, excepting in the case of the earths proper, it may be assumed that, when any metallic oxide is presented to any of the hydracids, water will be formed by the oxygen of the one, and the hydrogen of the other; while the metal and basacigen body will unite and, in a majority of instances, the metal will acquire the same number of atoms of the basacigen body, as it relinquishes of oxygen.

---

* Although I do not concur in the theoretic views which led to the employment of the word hydracid, yet as a convenient name for acids of which hydrogen is the radical, I shall occasionally use it. It is only on the same plea that the retention of the word oxygen can be justified by those who do not consider it as an acidifying principle.

It follows, of course, that on subjecting a mercurial oxide to chlorohydric, bromohydric, iodohydric, fluohydric, cyanhydric, sulphydric, selenhydric, or telluhydric acid, a chloride, bromide, iodide, fluoride, cyanide, sulphide, selenide, or telluride, will generally, if not universally, result.

Of the Chlorides of Mercury.

When a solution of chloride of sodium, and of nitrate of the protoxide of mercury are mingled, the oxygen of the oxide, and chlorine of the chloride exchange places; so that protochloride of mercury (calomel) precipitates, while the oxygen and sodium uniting, remain in solution, and in union with the nitric acid.

If the solution of chloride of sodium be added to a solution of the nitrate of the bioxide, the two atoms of oxygen in this oxide, will exchange places with the chlorine in two atoms of the chloride; so that the mercury will, for two atoms of oxygen, acquire a like number of atoms of chlorine, and be thus converted into one atom of bichloride, or corrosive sublimate, which will remain in solution, if there be enough water present. Thus the quantity of chlorine transferred, is regulated by the quantity of oxygen in the oxide employed; the protoxide producing the protochloride, the bioxide the bichloride.

The complex affinity which causes these changes, operates either in the wet or dry way; that is, whether the substances be mixed in solution, or sublimed together. The bisulphate of the bioxide of mercury produces these results, when sublimed with certain compounds of chlorine, as chloride of sodium for instance. Corrosive sublimate is thus procured; and, by trituration with mercury, a second sublimation, and washing in boiling water, may be converted into calomel; or the bisulphate, by trituration with a further portion of the metal, being converted into protosulphate, forms calomel directly by sublimation with common salt.

The process for the manufacture of the protochloride, has been improved by causing its nascent vapour to be mingled with steam, which, interposing between the particles, prevents them from adhering as they condense. They are thus obtained in a state of more minute division than could be effected by trituration, and the aqueous particles, in condensing, combine with and remove any particles of corrosive sublimate which may be generated simultaneously with those of the calomel. Calomel thus prepared, has been distinguished as Howard's hydrosublimate.

Chlorine does not combine with mercury in the indirect mode above mentioned only. A jet of chlorine burns spontaneously in mercurial vapour, forming a bichloride.

The chlorides of mercury may likewise be obtained by subjecting the oxides to chlorohydric acid; in which case the hydrogen of the acid, and oxygen of the oxide form water, while the mercury and chlorine unite; the protoxide giving rise to the protochloride, the bioxide to the bichloride, as already explained.

The processes for manufacturing these important compounds of mercury, are very numerous. They have, however, but one object—that of presenting chlorine and mercury to each other in due quantities, and intimately mingled. When the chlorine is in excess, corrosive sublimate is formed; when the metal predominates, calomel.

The *protochloride* is white and crystalline, but usually more compact than corrosive sublimate. It is tasteless, inodorous, and unalterable by exposure to the atmosphere if protected from light; but by this it is blackened, and partially reduced to the metallic state. It is blackened by alkaline solutions, by the generation of protoxide; and when the surface is removed, it appears yellow, so that a scratch made with the nail, is productive of a yellow streak. It is less volatile than the bichloride. This chloride acts as a base.

The *bichloride* or corrosive sublimate is white, more or less crystalline, and transparent. It is soluble in about twenty parts of cold water, but more so in hot water, whence crystals are obtained by refrigeration. It dissolves in two parts of alcohol, and in three parts of ether, by weight. It is not soluble either in sulphuric or nitric acid. On the application of heat, it sublimes unchanged. When added to an alkaline solution in excess, a yellow hydrated bioxide of mercury precipitates. The proportions being reversed, as when an alkaline solution is dropped into the solution of this chloride, a compound of the bioxide and bichloride is precipitated, which is of a brick-red colour. Berzelius designates this compound as the *chlorure mercurique basique*, while Thenard gives it the name of *bioxido-chlorure*. The latter appellation, changed to *oxychloride*, in order to render it consistent with the nomenclature adopted in this work, and more easy to pronounce, I shall employ for this, and for analogous compounds formed with other metals.[*]

Ammonia throws down from a solution of the bichloride, a compound called ammoniated mercury in the United States Pharmacopœia, but more generally known as hydrargyrum precipitatum album, or white precipitate. This is now considered by Thenard as a compound of ammonia with the bioxide and bichloride of mercury. Perhaps it may be well designated as an *ammoniacal oxychloride*.

The bichloride of mercury has a most nauseous metallic taste, and is a virulent poison. The best antidote for it is albumen, which may be given in the form of the white of eggs, diluted with water. This chloride, acting as an acid, combines with the chlorides of ammonium, potassium, sodium, barium, and magnesium. As a base it combines with chlorohydric acid, forming a crystalline compound, which effloresces and is decomposed when exposed to the air.

The salt, long known under the antiquated appellation of *sal alembroth*, and formed by mixing solutions of sal ammoniac and corrosive sublimate, is now by Berzelius considered as a double salt, and by Bonsdorf, a chlorohydrargyrate. This last mentioned name accords with the definition of acidity and basidity[†] which I have proposed.

[*] This compound probably furnishes one among many other instances, in which an electro-positive compound of one basacigen body, unites with an electro-negative compound of another.

It might indeed be alleged, that in this case the metal acts the part of a basacigen body, agreeably to my definition (see page 252); as it enters into two compounds, one electro-negative, the other electro-positive, which form a tertium quid. This view of the subject corroborates the remark, which I have elsewhere made, that nature has not fitted her bodies for distinct classification; and that consequently there will be cases, in which some of the bodies associated in one class, will appear to belong to another.

[†] I believe that this word is unauthorized, but as among chemists there is nearly as much occasion for it, as for its well known correlative, *acidity;* and as any reader who understands the one, cannot fail to interpret the other, I hope that this innovation will be deemed justifiable.

Of the Bromides, Iodides, Fluorides, and Cyanides of Mercury.

As respects the means of their production, the ratio of their constituent atoms, and their qualities in general, there is the greatest analogy between the compounds formed by mercury with the halogen class. Hence, having treated particularly of the chlorides, I shall treat with the utmost brevity of the compounds named at the head of this article.

Bromine forms two compounds with mercury. The ***protobromide*** is white, pulverulent, and insoluble. It is obtained by the reaction of the bromide of potassium with the nitrate of the protoxide of mercury.

The ***bibromide*** is formed by subjecting mercury to the action of bromine and water. It is soluble, crystallizable, fusible, capable of volatilization, and colourless. With the alkaline bromides it acts as an acid.

The ***protiodide of mercury*** is obtained by the reaction of the iodide of potassium with the nitrate of the protoxide of mercury. It is olive coloured, insoluble in water, and corresponds in composition with the protoxide.

The ***biiodide*** may be procured by adding the iodide of potassium to a solution of the bichloride of mercury. A reciprocal decomposition takes place, and the biiodide of mercury and the chloride of potassium are formed. The biiodide is fusible, volatile, and of a transcendently beautiful scarlet colour. As an acid it combines with the iodides of many of the earths and alkalies, and with the iodides of zinc and iron. As a base it unites with iodohydric acid. It consists of one atom of mercury, combined with two atoms of iodine.

Another iodide exists, containing less iodine than the biiodide, but more than the protiodide.

Although cyanogen does not combine with mercury directly, a ***bicyanide*** is obtained when the bioxide of this metal is digested in water with Prussian blue. I shall more fully explain this process when treating of iron.

The employment of the bicyanide in the evolution of cyanogen and cyanhydric acid, has already been mentioned. The bicyanide of mercury forms combinations with the alkaline cyanides, in which it plays the part of an acid.

The ***fluoride of mercury*** is obtained by the action of fluohydric acid on the bioxide. It acts both as an acid and base. It is yellow, volatile, and when volatilized in platinum or glass vessels, corrodes them. If subjected to water, it is resolved into a soluble and an insoluble compound.

Of the Compounds of Mercury with Sulphur.

Agreeably to the list of equivalents near the beginning of this article, mercury forms with sulphur, a protosulphide and a bisulphide. When a weak solution of the nitrate of the protoxide of mercury is impregnated with sulphydric acid, the *protosulphide* is produced in the form of a black precipitate. It appears to be an unimportant compound. The protosulphide acts as a sulphobase.*

*** Guibourt, who has been mentioned as questioning the existence of more t one oxide of mercury, has alleged his disbelief in the existence of more than**

The *bisulphide* may be generated by impregnating with the same gas a solution of the bichloride. Thus obtained, it resembles the protosulphide in assuming a black colour, which, however, may be changed to red by sublimation.

The bisulphide (artificial cinnabar) is procured in the large way, by fusing one part of sulphur, stirring in gradually six or seven of mercury, and subjecting the resulting black mass to the process of sublimation in close vessels.

Kirchoff procured cinnabar by a long continued trituration of mercury and sulphur with a solution of caustic potash, aided by a gentle heat.

Bisulphide of mercury is attacked neither by sulphuric, nitric, nor chlorohydric acid, nor by caustic alkaline solutions; but when subjected to chlorine, either in aqueous solution as in aqua regia, or in the gaseous form, it is converted into bichloride of mercury, and bichloride of sulphur.

Berzelius alleges that this bisulphide performs the part of a base in combining with the aëriform sulphacids. It also forms compounds with the bichloride, bibromide, biiodide, and bifluoride of mercury.

Equal parts by weight of mercury and sulphur, triturated together, form a black mass, called, from its colour, *Ethiops mineral*, which is now considered as a mixture of bisulphide of mercury and sulphur.

Of the Phosphurets of Mercury.

In its habitudes with mercury, phosphorus displays that analogy with sulphur which is in general so remarkable. It forms, according to Berzelius, a red and a black phosphuret. The latter results from the digestion of bioxide of mercury with phosphorus and water; the former, from exposing phosphorus to the vapours of the bichloride of mercury.

Of the Alloys of Mercury with other Metals, called Amalgams.

All metals combine with mercury, directly or indirectly. Its compounds have the generic name of amalgams. In the case of gold, silver, zinc, lead, tin, and bismuth, the amalgamation is rapidly effected. It is less easily produced with copper, unless when this metal separates mercury from the acids. It is difficult to unite mercury with platinum, and

---

mercurial sulphide; the black sulphide being, in his opinion, a mixture of the red with the metal. Seftstrom controverts this allegation, and Thenard, citing his opinions and that of Guibourt, inclines in favour of those of Seftstrom. Thenard alleges that at least the protosulphide exists as a base, in combination with sulphides, acting of course as sulphacids, agreeably to my definition, page 252.

till more so with iron, owing, probably, to the great difference in fusiility.

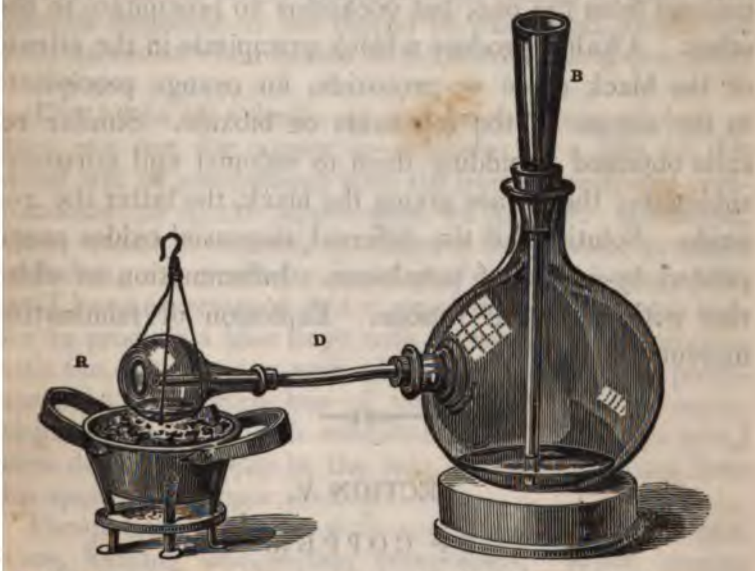
Mercury unites energetically with the metals of the alkalies. In the ase of sodium, a species of combustion ensues, so that the mass becomes ed-hot; and when sodium is thrown upon mercury, it is repelled with vionce, and with a disengagement of light.

The amalgam of potassium is an efficient instrument in the evolution of mmonium.

255. *Combustion of Mercury with Chlorine.*

This experiment may be performed by means of the apparatus repreented by the following cut. Let there be a glass globe, furnished with a eck and tubulure, and holding about two gallons of chlorine. Into the eck, let a trumpet-shaped tube, B, reaching to the bottom, be fastened airght by means of a cork.

Let another tube, about fifteen inches in length, and tapering towards ne end, so as to form a capillary orifice, be fastened, at the other end, nto the lateral tubulure of the globe. Provide a globular receiver, R, ith a neck on one side, and a perforation on the other, opposite the neck.



Let the lower part of this vessel be occupied by about a gill of mercury, nd exposed to a chauffer of coals, so as to fill the whole cavity of the essel with the vaporized metal. Under these circumstances, introduce e pipe, D, proceeding from the lateral tubulure, into the neck of the reeiver, so that the capillary orifice may be near the perforation; and imediately afterwards pour chlorohydric acid into the tube, B. This will ubject the chlorine to pressure without absorbing it, and consequently ause it to escape in a jet from the capillary orifice in the pipe. Hence, ingling with the vaporized mercury, it will produce a feebly luminous ame.

Instead of using the globe and its appendages, I have, in a majority of instances, employed a tubulated retort, with a long narrow beak, for the production of the jet of chlorine. The retort being sufficiently supplied with manganese, and a glass funnel with a cock being fastened into the tubulure, as much chlorohydric acid is allowed to enter through the funnel, as will generate a sufficient quantity of chlorine to produce a jet from the capillary orifice, in which the beak of the retort is purposely made to terminate. The beak of the retort being made to occupy the place of the tube, represented in the figure as proceeding from the globe, the experiment is, in other respects, the same as that above described.

256. *Experimental Illustrations.*

Ebullition and distillation of mercury. Its compounds with oxygen and sulphur, exhibited. Action of nitric acid and of sulphuric acid on the metal. Resulting salts, subjected to hot water. Black oxide and red oxide, severally dissolved in nitric acid. Chlorohydric acid precipitates calomel from the one, but occasions no precipitate in the other. Alkalies produce a black precipitate in the nitrate of the black oxide or protoxide, an orange precipitate in the nitrate of the red oxide or bioxide. Similar results obtained by adding them to calomel and corrosive sublimate; the former giving the black, the latter the red oxide. Solutions of the different mercurial oxides precipitated by iodide of potassium. Inflammation of chlorine with mercurial vapour. Explosion of fulminating mercury.

SECTION V.

OF COPPER.

Copper is occasionally found in nature in the metallic state; also in the states of oxide, carbonate, and sulphide. It is obtained principally from the sulphide. The sulphur being acidified and volatilized, and the metal oxidized by torrefaction, the resulting oxide is decomposed by heat and charcoal.

The copper of commerce contains, according to Berzelius, a minute portion of sulphur and carbon. It may be purified by solution in concentrated and boiling chloroydric acid, and subsequent precipitation by a bright plate f iron.

Properties.—The lustre and peculiar colour of this me-al are too well known to need description. Excepting itanium, it is the only red metal. It is very malleable nd ductile, and next to iron in tenacity. Its specific ravity is nearly 9. It fuses at a white heat.

If a current of ammoniacal gas be passed over copper, eated to bright redness in a tube, the gas is decomposed, nd the copper becomes brittle, although its weight is but lightly, if at all increased. This change is supposed to e due to a different aggregation of the particles of the opper, induced by the formation and subsequent decom-osition of a nitruret of copper.

Alloyed with a small quantity of tin, copper forms ronze; with a larger quantity, bell metal. Fused with inc, or subjected to the vapour of this metal, as evolved rom calamine when heated with charcoal, it is converted nto brass.

The blade of a knife, or any bright piece of iron or teel, is a test for copper in solution; as a film of this etal will be precipitated upon the iron or steel, and com-unicate to it the appearance of copper. Ammonia, vhen added in excess, produces a blue colour in water ontaining a very minute quantity of copper, see page 136; ut I have ascertained that it requires twice as much cop-er to produce a blue tinge with ammonia, as to produce vith the cyanoferrous acid of the cyanoferrite of potas-ium, the appropriate hue of the cyanoferrite of copper, vhich is a peculiar rich reddish-brown. With this test I ave detected copper in the rain water, proceeding from he spout of a copper roof.

Phosphorus combines with copper in various propor-ions, forming unimportant compounds. When present n small quantity, it has an effect upon this metal similar o that which carbon has on iron, rendering the copper ard enough for cutting instruments. Carbon and silicon oth combine with copper.

The equivalents of copper, and of its compounds with xygen, chlorine, and sulphur, are as follows:—

opper,	- - - - - - -	32
ed or dioxide,	2 atoms copper with 1 atom oxygen,	72
lack or protoxide,	1 atom ,, 1 atom ,,	40

Superoxide,	1 atom copper with	2 atoms oxygen,	48
Dichloride,	2 atoms „	1 atom „	100
Protochloride,	1 atom „	1 atom „	68
Disulphide,	2 atoms „	1 atom „	80
Protosulphide,	1 atom „	1 atom „	48

Of the Compounds of Copper with Oxygen.

There are three oxides of copper, a dioxide, a protoxide, and a superoxide.

Every one is familiar with the appearance of the *dioxide;* since it forms the dull red exterior coating of copper, as it comes to us from the manufacturer. When this oxide is subjected to liquid chlorohydric acid, a double decomposition ensues, and water and a dichloride of copper are formed, the latter remaining in solution. Subjected to nitric acid, the dioxide is converted into protoxide by one portion of the acid, and dissolved by the other. By igniting the protoxide with metallic copper, the anhydrous dioxide is produced. On mingling solutions of potash and of the dichloride, an orange-coloured hydrate of the dioxide precipitates. It is difficult to wash and dry this compound without partially converting it into protoxide.

The *protoxide of copper* is of a brownish-black colour. It is formed upon sheet copper, when exposed to a bright red heat with access of air. To obtain it, however, Thenard recommends that the nitrate or sulphate be intensely ignited in a stoneware retort, by which means the acid is volatilized, and the protoxide remains. This oxide is formed when copper is dissolved in nitric or sulphuric acid, and enters into combination with them, forming a nitrate, or sulphate.

Thenard alleges that it is soluble in ammonia, only when combined with water or some acid; and that it is insoluble in the fixed alkalies, whether hydrous or anhydrous.

That the fixed alkalies promote its oxidizement, is evident; since sheet copper, or brass, moistened with alkaline solutions, always becomes green in the air. I think it probable, that carbonic acid co-operates in producing this result.

The *superoxide of copper* is formed by mingling the bioxide (deutoxide) of hydrogen with a weak solution of nitrate of copper, and adding just enough alkali to decompose all the nitrate. These conditions being realized, brownish-yellow gelatinous mass subsides, which, after eing washed upon a filter with cold water, and dried in he vacuum of an air pump over sulphuric acid, forms the uperoxide. This oxide has no taste or smell.

The dioxide of copper acts feebly as a base, the protxide energetically, and the superoxide plays the part either of a base nor of an acid.

Nitric acid diluted nearly to the specific gravity of 1.2, rotoxidizes and dissolves copper, producing a blue solu-ion, which yields, by evaporation, elegant blue crystals. The ignition which ensues when these crystals are pul-erized, moistened, and rolled up in tinfoil, has been ad-luced as an exemplification of the influence of water in romoting chemical reaction.

The crystals of nitrate of copper are of a deeper blue han those of the sulphate, and are deliquescent. At a noderate temperature, these crystals fuse, and lose a part of their water of crystallization.

Sulphuric acid, boiled on copper, oxidizes and dissolves it, as nitric acid does without heat. The resulting compound forms the blue crystals of sulphate, called in com-nerce *blue vitriol* or *blue stone*.

A compound is obtained by triturating sulphate of copper with carbonate of ammonia, called *cuprum ammoniatum* (ammoniated copper) in the Pharmacopœias.

This contains the ammoniacal sulphate of copper, with some portion of the carbonate undecomposed. It may be a mixture of ammoniacal sulphate, and ammoniacal carbonate of copper. It is designated as ammoniated copper in the United States Dispensatory; and the authors allege that there is some obscurity as to the mode in which its ingredients are associated. It has been stated above, that the protoxide of copper is not soluble in ammonia, unless when united with water acting as hydric acid, or with some other substance capable of performing the part of an acid. Berzelius mentions that the protoxide of copper may be kept in a bottle containing liquid ammonia, without tinging it blue; but that the introduction of only a few drops of any ammoniacal salt, the carbonate for instance, causes the well known striking blue colour of cuprum ammoniatum, formerly called aqua sapphirina. He also alleges that cuprum ammoniatum contains the ingredients in such proportion, that the alkali saturates twice as much acid as the copper.

Of the Compounds of the Oxides of Copper with Acetic Acid.

The oxides of copper form salts with almost every acid, whether mineral or vegetable. Among these, none are better known than its combinations with acetic acid, of which one is designated in commerce as verdigris, the other as distilled verdigris, or crystals of Venus.

Crude verdigris is a mixture of neutral acetate and subacetate of copper, with some impurities.

The neutral acetate crystallizes readily, and in the crystalline form has received the name of crystals of Venus; Venus having been one of the names given to copper by the old chemists.

The subacetate consists of one atom of acid to two of protoxide, while the neutral acetate consists of one atom of each constituent.

The salts of the protoxide of copper are all of an intensely blue or green colour. This does not appear to be true in the case of the dioxide; since, according to Berzelius, when verdigris is subjected to heat, colourless crystals of the acetate of the dioxide sublime, so as nearly to fill the beak of the retort. Thenard alleges that when the hydrated dioxide is subjected to liquid ammonia, a colourless solution of it results.

Of the Compounds of Copper with the Halogen Class.

A chlorohydrate of the dichloride of copper acting as a chlorobase, may be prepared by the action of chlorohydric acid on a mixture of the protoxide of copper, and finely divided metallic copper. From this chlorohydrate, the dichloride may be precipitated by water. It is likewise produced by heating the protochloride in close vessels, by which one-half of the chlorine is expelled. This chloride may also be obtained from the protochloride, by digestion in chlorohydric acid with copper shreds or filings. When thus evolved, it subsides in crystals, which can only be dried in vacuo over sulphuric acid; as in the air they are converted into a compound of the dioxide with the protochloride, for which, as I have already stated, I shall adopt the name of oxychloride.

The dichloride is soluble, crystallizable, and fusible by heat. It consists of two atoms of copper, and one of chlorine.

The protochloride may be formed either by the reaction of chlorohydric acid with the protoxide, or by the combustion of copper wire or leaves in chlorine. It is of a blueish-green colour, and an astringent taste. It is crystallizable, fusible, and decomposable by heat. This chloride attracts

isture, and is very soluble in water. Characters written with a solu-
n of it, remain invisible until heated, when they become yellow. It
nstitutes, of course, a species of sympathetic ink.

The protochloride acts as an acid with the chlorides of potassium and
nmonium, and with other chlorobases, forming with them chlorocuprates.

No compound of copper with bromine is mentioned by Berzelius or
henard. Those formed with iodine appear feeble and unimportant. With
orine, copper forms two compounds, a protofluoride, and a perfluoride.
he protofluoride acts as a base, the perfluoride both as a base and an
id. Cyanogen enters into combination with copper in two different
oportions.

Of the Compounds of Copper with Sulphur and Selenium.

Copper forms with sulphur, a disulphide, containing two atoms of metal,
d one of sulphur, and a protosulphide, in which, as its name implies,
e atom of copper is united to one of sulphur. The former may be pro-
ced by the fusion of the metal, or its oxide with sulphur. It is found
re in nature, and likewise combined in definite proportions with the sul-
ides of antimony, arsenic, bismuth, and iron, in which case the sulphur
usually divided equally between the metals. Berzelius alleges this
lphide to be a powerful sulphobase. Yet, in its combination with the
lphide of iron, it cannot be supposed to act as a base, as iron is more
ctro-positive than copper. The affinity between the last mentioned
lphides is so energetic, that the resulting sulphocuprate cannot be decom-
sed by the united action of carbon and a fixed alkali.

The protosulphide of copper is formed, when a solution of the metal is
ecipitated by sulphydric acid. This sulphide is alleged to act as a sul-
obase.

Copper, by fusion with various sulphides of the alkalifiable metals, is
ade to unite with several proportions of sulphur, but the resulting com-
unds are unimportant.

The union of copper with selenium is productive of heat and light; in
hich respect, as in others, the analogy between selenium and sulphur is
stained. The resulting compound is a diselenide. It is found in na-
re, but does not appear to have any striking qualities. A protoselenide
formed when copper is precipitated by selenhydric acid.

257. *Experimental Illustrations.*

Solution of copper in nitric acid, and its precipitation
y iron. Effect of ammonia on a solution of copper; also
f cyanoferrite of potassium. Crystals of the sulphate,
itrate, acetate, and subacetate, exhibited; also solutions.
xhibition of the protoxide, and of copper sheets dioxi-
ized as usual.

SECTION VI.

OF LEAD.

Lead is found in nature, in union with sulphur and with oxygen, and likewise united, in the state of an oxybase, severally with chromic, sulphuric, phosphoric, molybdic, carbonic, and arsenic acids.

Lead is procured chiefly from the native sulphide, known among miners and mineralogists under the name of *galena*, which is the most abundant and prolific of its ores. The metal is liberated from galena by exposing it to the flame of a reverberatory furnace, which, oxidizing and expelling the sulphur, liberates the lead from combination with it, partially in the state of oxide, principally in the metallic state. The protoxide of this metal in a semivitrified state, called litharge, is largely obtained in the process of cupellation, already described as the means of procuring silver from argentiferous galena, or from alloys in which it exists in union with more oxidizable metals.

From any of its oxides, the metal is easily obtained by heat and charcoal.

In the small way, a great majority of its combinations will yield a metallic globule, by exposure, on charcoal, to the deoxidizing or carbonaceous flame of the blowpipe.

Properties.—The colour, lustre, and malleability of lead are well known. It fuses at about 600° F. Its specific gravity is 11.352. In large masses it is pre-eminently ductile, as it may be drawn into pipes of four inches bore; but it is too deficient in tenacity to be drawn into fine wire. It is very useful to chemists, being employed to construct the chambers and vessels, used in the manufacture of sulphuric acid and chlorine. Lead combines with carbon, silicon, and phosphorus.

Of the Compounds of Lead with Oxygen.

The following are the only known compounds of lead with oxygen.

Dioxide, or *dross*, probably	2 atoms lead,	208
	1 atom oxygen,	8
		216

Protoxide, - -	1 atom lead,	104
	1 atom oxygen,	8
		112
Bioxide, - -	1 atom lead,	104
	2 atoms oxygen,	16
		120
Red oxide or minium,	3 atoms lead,	312
	4 atoms oxygen,	32
		344

The *protoxide of lead*, as we find it in the shops under the appellation of litharge, is of a yellow colour when in mass, but reddish yellow when pulverized. In the pulverulent form it is known in commerce by the name of *massicot*. It appears to be soluble in pure water, but is rendered insoluble by the presence of the smallest quantity of chloride of sodium or of any earthy matter. The protoxide of lead plays the part both of an acid and a base. In the latter capacity, it unites with the more powerful acids; in the former, with the earths and alkalies.

When the protoxide of lead is powdered and heated nearly to redness, and then suffered to cool slowly, it is converted into a substance called *minium* or *red lead*, which is largely consumed as one of the materials of flint glass. Formerly minium was considered as a distinct oxide, and to this view of its composition Berzelius inclines. Thenard alleges, upon the authority of experiments made by Dumas, that it consists of three atoms of lead united to four of oxygen, and infers that it is a compound of one atom of the bioxide, and two of the protoxide.

When minium is exposed to a red heat, it evolves oxygen, and is converted into the protoxide.

The *bioxide of lead* is obtained by the action of nitric acid on minium. One portion of the minium is decomposed, and yields its oxygen to another portion, forming the bioxide. At the close of the operation, a bioxide, and a nitrate of the protoxide are obtained.

The bioxide is of a flea colour, and is convertible by heat, first into minium, and then into protoxide. When triturated with sulphur, inflammation ensues. According to Thenard, this oxide never acts as a base, and but seldom as an acid.

Berzelius alleges that the gray pellicle or dross, which forms on the surface of lead when exposed to the air, and which accumulates in greater quantities when the metal is heated, is a dioxide of lead. He also states that this oxide may be obtained by the decomposition of oxalate of lead by heat. Some recent experiments of Mr. Boussingault tend to confirm this opinion.

The habitudes of lead with nitric, sulphuric, and chlorohydric acid, are so analogous to those of mercury with the same acids, that I do not deem it necessary to do more than point out the analogy; at the same time mentioning that, in the case of lead, no compounds are formed by oxacids with any oxide besides the protoxide; and that the resulting compounds have an insolubility more marked and invariable. Excepting the acetate and nitrate, there is scarcely an important compound formed by an acid with this metal, which is soluble in water; and consequently there are no important soluble salts besides those formed with acetic and nitric acid, which do not, by complex affinity, precipitate lead from its solutions.

Of the Compounds of the Protoxide of Lead with Acetic Acid.

Lead is oxidized and dissolved by acetic acid, and forms the acetate, called in commerce *sugar of lead.*

This name was given to the acetate of lead in consequence of its taste, which is sweet and astringent. It is crystallizable, soluble in water, and decomposable by heat.

The acetate of lead, consisting of one atom of oxide, and one atom of acetic acid, by digestion with the protoxide, whether in the form of litharge or of massicot, may take either one or two additional atoms of oxide, forming a *diacetate* consisting of two atoms of oxide and one of acid, or a *trisacetate*, consisting of three atoms of oxide and one of acid.

By *boiling* a solution of the acetate upon an excess of the protoxide, a *hexacetate* may be obtained, consisting of six atoms of oxide and one of acid. This compound may be produced also, by decomposing the acetate by an excess of ammonia. It forms, when dried, a white powder, slightly soluble in boiling, but insoluble in cold water.

Goulard's extract, of which one *fluidrachm*, agreeably to the U. S. Pharmacopœia, is to be added to a pint of distilled water to make *lead-water*, is usually considered as a diacetate, and called the subacetate; but from the formula, it must be evident that it may contain enough oxide to make it partially, if not wholly, a trisacetate.

It appears to me that medical practitioners, if not ignorant of the difference which exists in composition between these acetates, are too inattentive to the possible diversity of their effects.

When an acetate, containing more than the proportion of one atom of oxide to one of acid, is brought into contact with carbonic acid gas, a precipitate ensues of carbonate of lead. Hence lead-water may be used as a test for carbonic acid, producing results on breathing into it, or upon adding it to a solution of any carbonate, analogous to those produced by lime-water under like circumstances.

Of Carbonate of Lead.

When exposed to the fumes of vinegar, which consist of acetic acid and carbonic acid gas, lead is oxidized by the acetic acid, and combines with the carbonic acid, forming ceruse, or the white lead of commerce.

According to Thenard, the best process for obtaining the carbonate of lead, is to pass carbonic acid through a solution of the diacetate. Half the lead is precipitated in the state of carbonate, and the remainder continues in solution as an acetate. The solution of acetate is reduced to a diacetate by boiling it with oxide of lead, and subjected to carbonic acid as before. In this way carbonate of lead of the best quality is procured without losing any of the acetic acid. Carbonate of lead is found in nature.

Of the Compounds of Lead with the Halogen Class.

The analogy between the habitudes of lead and mercury with acids, alluded to above, is not greater than that which exists between their habitudes with the halogen bodies. Analogous reciprocal decompositions ensue, whether solutions of the soluble oxysalts of lead or mercury be mingled with solutions of chlorides, bromides, iodides, fluorides, or cyanides of the alkalifiable metals.

The chloride of lead is white, crystallizable, soluble in thirty times its weight of water, and has a sweet and astringent taste. When exposed to a red heat it melts, and forms a mass formerly called *plumbum corneum*, from its resemblance to horn. If the heat be pushed to redness, and the access of air be permitted, the chloride is partially volatilized; and the remainder is found to consist of oxide and chloride, or, in other words, to constitute one of those compounds called by Thenard *oxido-chlorures*, and which I call *oxychlorides*.* Several other oxychlorides exist, containing the oxide of lead, united to the chloride in various proportions. One of these is found native in England.

The bromide, iodide, fluoride, and cyanide of lead, which may, as abovementioned, be generated by means analogous to those by which the chloride is obtained, are of too little practical importance to make it expedient to notice them particularly.

The fluoride acts as a fluobase, the cyanide as a cyanobase. The former combines with the fluacids of boron and silicon, the latter with cyanoferrous acid.

Of the Compounds of Lead with Sulphur and Selenium.

Sulphur forms three compounds with lead, a disulphide, a protosulphide, and a persulphide. Of these, the only compound which I deem it proper to notice, is the protosulphide, which has already been adverted to as the principal ore of lead, called galena. This sulphide may be formed artificially by heating lead and sulphur together. The protosulphide of lead is tasteless, inodorous, indecomposable by heat, and less fusible than lead. It acts as a sulphobase, and is composed of one atom of lead, united to one atom of sulphur.

The selenide of lead may be procured by exposing lead, mingled with selenium, to heat. When thus obtained it is gray, but by friction it becomes polished and white like silver. It is found in nature.

258. *Experimental Illustrations.*

Solution of lead in nitric acid. Its solutions precipitated by sulphates, chlorides, phosphates, and chromates. Also by sulphydric acid. Precipitation of carbonate of lead from the subacetate by the carbonic acid of the breath. Galena decomposed by the blowpipe flame.

---

* I adopted this name without knowing that it had been employed by other chemists, as I have since learned. This coincidence of opinion without consultation, tends to show the influence of the principles of nomenclature in producing in different minds like results.

◆

SECTION VII.

OF TIN.

This metal is found in the state of oxide, and in that of sulphide. The sulphide is rare, and contains much copper. The ore of tin, which is the principal source of the metal, is the bioxide which is reduced by heat and charcoal. Tin is sold in commerce under the name of *Block tin*, to distinguish it from tinned iron plates, vulgarly called tin.

Properties.—The colour and lustre of tin may be seen in utensils newly made of tinned iron. It is very malleable and ductile; tin foil being only $\frac{1}{1000}$th of an inch thick. Tin tarnishes slightly by exposure to the air. Its specific gravity is 7.9. It melts at 442° F. It is distinguished by producing a peculiar crackling noise, when its ingots are bent to and fro.

The equivalents of tin, and of its compounds with oxygen, chlorine, and sulphur, are as follows:—

Tin	-	-	-	59
Protoxide	1	atom metal,	1 oxygen,	67
Bioxide	1	„	2 „	75
Protochloride	1	„	1 chlorine,	95
Bichloride	1	„	2 „	131
Protosulphide	1	„	1 sulphur,	75
Bisulphide	1	„	2 „	91

Of the Compounds of Tin with Oxygen.

The protoxide of tin, consisting of one atom of metal and one of oxygen, may be procured by adding potash to the protochloride. A reciprocal decomposition takes place between the oxide of potassium and protochloride of tin, which results in the formation of the chloride of potassium, and protoxide of tin. The former remains in solution, and the latter precipitates in the state of a white hydrate. From this hydrate the water may be expelled by heat; and a grayish-black anhydrous protoxide is thus obtained, which is liable, by contact with an ignited body, to take fire, and consequently to be converted into the bioxide. The hydrate is likewise combustible, though in a less degree.

The hydrated bioxide of tin may be speedily obtained by the tin foil or tin powder with concentrated nitric acid, which is with great violence, bioxidizing the metal without dissolving it. This oxide may be obtained in the same hydrated state, by precipitation from the bichloride by an alkali. The hydrates thus obtained, though in composition the same, are different in properties. Both are soluble in alkalies, but only the latter is soluble in acids. This diversity continues even after they are severally dissolved by alkaline solutions, and subsequently precipitated by acids. These hydrated bioxides of tin are, therefore, conceived to present a case of isomerism. (See page 268.)

We may convert the bioxide, as obtained by means of nitric acid, into the other modification, by first changing it into a chloride, and then precipitating it by potash.

According to Thenard, if the precipitated bioxide be subjected to heat, it becomes insoluble in acids.

An anhydrous bioxide of tin may be obtained by subjecting tin to intense heat in contact with air. It is white, infusible, and indecomposable by heat. It reddens moistened litmus paper when placed on it. This oxide is frequently found crystallized in nature. It is employed in the arts for the manufacture of enamel, and, under the name of putty, in grinding glass, and in making a paste for hones. The bioxide of tin acts both as an oxacid and an oxybase, combining, under favourable circumstances, with either acids or alkalies.

Concentrated sulphuric acid, when cold, has no action on tin, but with the assistance of heat dissolves it, disengaging sulphurous acid gas, and forming a sulphate of the protoxide or bioxide.

The addition of concentrated nitric acid to powdered tin, is followed by a rise of temperature, a decomposition of the acid, the evolution of nitrogen nearly pure, and the formation of the bioxide of tin. If the nitric acid be diluted so as to have a specific gravity of 1.114, and the temperature be prevented from rising by cold water, or other refrigerating applications, no gas is disengaged; since, water being decomposed simultaneously with a portion of the acid, the nitrogen and hydrogen which are thus liberated, unite to form ammonia. This combines with part of the nitric acid; so that at the close of the operation we obtain nitrate of ammonia, mingled with the nitrate of the protoxide of tin.

Of the Compounds of Tin with the Halogen Class.

A crystalline hydrate of the ***protochloride of tin***, may be obtained by subjecting the metal, in a divided state, to the action of chlorohydric acid, and then crystallizing the resulting solution by evaporation. The protochloride may be procured in an anhydrous state, either by subjecting this hydrate to a temperature sufficiently high to drive off the water, or by exposing a mixture of the bichloride of mercury and metallic tin to a red heat. When exposed, either in the solid state or in that of solution, to the action of the air, or of liquids containing oxygen, the protochloride attracts that gas, and is converted into an oxychloride. (See note, page 358.) It is possible that in this case a portion of the protochloride is decomposed, the chlorine forming a bichloride with the remainder, and the liberated metal uniting with the oxygen.

The protochloride of tin acts as an acid. It is composed of one atom of tin, and one of chlorine.

The ***bichloride of tin*** may be obtained in the anhydrous state, by gently hea [illegible] ixture of metallic tin with the bichloride of mercury. The bi[illegible] colourless liquid, possessing an acrid taste. It is volatile, and hen exposed to the air produces dense and suffocating fumes. It is still ccasionally called by its ancient name of the *fuming liquor of Libavius.* y the addition of one-third of its weight of water, this bichloride forms a olid crystallizable hydrate, which, nevertheless, dissolves on the addition f a sufficient quantity of water.

Iodine, bromine, and fluorine severally combine with tin in two proportions. The perfluoride of tin acts as a base.

The cyanides of tin have never been isolated. Berzelius, however, states, that they exist in combination with those of iron, in which case they probably play the part of cyanobases.

Of the Compounds of Tin with Sulphur and Selenium.

The *protosulphide of tin* is obtained by heating, in a crucible, three parts of finely divided tin, and two of flowers of sulphur. This sulphide is solid, crystallizable, indecomposable by heat, less fusible than tin, and acts as a sulphobase. It is composed of an atom of tin, united to an atom of sulphur.

The ***bisulphide of tin*** is obtained by exposing to heat in a coated glass matrass, a mixture of two parts of tin, one and a half of sulphur, one of mercury, and one of sal ammoniac.*

The bisulphide of tin, generally known as ***aurum musivum***, or ***mosaic gold***, is of a beautiful golden yellow. When exposed to a red heat, it is decomposed. It acts feebly as a sulphobase, and powerfully as a sulphacid. This sulphide, when spread on the surface of the cushion of electrical machines, has been found to increase their exciting power.

According to Berzelius there is a third sulphide, which contains a quantity of sulphur, intermediate between those which exist in the protosulphide and the bisulphide.

A gray ***selenide of tin*** may be procured by gently heating finely divided tin with selenium.

259. *Experimental Illustrations.*

Exhibition of tin and of tin foil; also of the fuming liquor of Libavius. Reaction of nitric acid or nitrate of copper with tin powder. Solution of tin by chlorohydric acid, and effects of the chloride thus obtained on some other metallic solutions. Decoloration of ink and Prussian blue. Ammonia evolved by a solution of tin in dilute nitric acid. Bisulphide exhibited.

---

* Berzelius suggests that the mercury probably acts by bringing the tin into a state of more intimate mixture with the sulphur; and the sal ammoniac, by carrying off, in consequence of its volatility, the heat which is evolved during the union of the sulphur with the tin, and which would otherwise be sufficient to decompose the bisulphide, were it already formed.

SECTION VIII.

OF BISMUTH.

This metal is found in nature in the metallic s usually, however, containing a little cobalt and ars and sometimes sulphur. It is also found in the sta sulphide.

According to Cleaveland, the only ore of bismuth w is explored, is that in which it exists in the metallic s From this it is evolved by exposure to a wood fire, u which a hole is made to receive the melted metal.

According to Berzelius, the bismuth of commerce tains iron and arsenic, and perhaps other metals. order to purify it, it should be dissolved in nitric acid resulting clear solution should be mingled with wate which a pure hydrated subnitrate of bismuth is precipit The precipitate being dried, is reduced by the aid of l flux and a gentle heat.

Properties.—Bismuth is brittle, easily reduced to der, and of a silvery white colour, tinged with red. pre-eminent for the facility and regularity with whi crystallizes. Its fracture is always crystalline. Th alleges that, when quite pure, its crystals are cubes, w are so associated as to form a four-sided inverted mid, in which the faces resemble stairs. Its specific vity is 9.82. It is usually considered as unmalleable Turner alleges that it may be hammered into plates warm. Excepting mercury and tin, it is the most fi of the metals proper. Its fusing point is 476°. It is dized when kept in fusion in the air; but not other unless the air be moist, in which case it is tarnished. muth combines with phosphorus, and probably in a m proportion with hydrogen. Its equivalent is 71.

The action of sulphuric or nitric acid on bismut very similar to the action of the same acids on tin. N acid, perhaps, acts more violently on the former than on the latter; since the addition of a small qua of concentrated nitric acid to powdered bismuth, c the evolution of so much heat as to raise the temper of the mass to redness. The hydrated subnitrate o muth, obtained as abovementioned by subjecting th trate to water, is of a fine white colour, and has called *magistery of bismuth*. If chlorohydric acid be present in the solution, the precipitate assumes the form of minute scales, of a pearly lustre, called *pearl white*. These precipitates have been used as pigments to improve the complexion, but are liable to be rendered black by sulphydric acid.

Of the Compounds of Bismuth with Oxygen.

There are two oxides of bismuth; one is a protoxide, consisting of one atom of metal, and one of oxygen; the other a sesquioxide, composed, consequently, of two atoms of metal, and three of oxygen.

The protoxide may be obtained by heating bismuth with access of atmospheric oxygen, or by the calcination of the nitrate. When the subnitrate (magistery) of bismuth is subjected successively to a caustic alkaline solution, and to cold water, it forms a white hydrated protoxide of bismuth. This oxide, when anhydrous, is yellowish, fusible at a red heat, devoid of affinity for atmospheric oxygen, and easily reducible when heated with carbon or hydrogen. It acts as a base.

The sesquioxide of bismuth is obtained by boiling the protoxide with a solution of the chloride of potash or soda.* It is of a deep brown colour, and, at a temperature a little below the boiling point of mercury, is decomposed. The sesquioxide of bismuth acts neither as a base nor as an acid.

Of the Compounds of Bismuth with the Halogen Class.

Either directly or indirectly, compounds of bismuth may be produced with all the halogen bodies.

In chlorine this metal takes fire spontaneously, forming a compound which, from the butyraceous consistency assumed in melting, received from the old chemists the appellation of the ***butter of bismuth***. This chloride may also be obtained in the anhydrous state, by heating three parts of the bichloride of mercury with one of bismuth. The anhydrous chloride is white, volatile, and deliquescent. When subjected to water, a white insoluble oxychloride† is formed.

A crystalline hydrate of the chloride of bismuth may be formed by dissolving bismuth in aqua regia, and evaporating the solution. The chloride of bismuth is composed of one atom of bismuth and one of chlorine.

Bromides of bismuth may be obtained by heating bismuth with bromine. Iodides may be produced in like manner.

---

* Thenard, Traité de Chimie, 6ème ed. ii. 484.

† By *oxychloride* I mean, as already stated, a compound consisting of an oxide and a chloride, called by Thenard, *oxido-chlorure*, by Berzelius, *chlorure basique*.

Fluorine and cyanogen both combine with bismuth. The cyanide, however, is known only in a state of combination.

Of the Compounds of Bismuth with Sulphur and Selenium.

Bismuth forms a bisulphide when heated with sulphur. At the moment when the combination takes place, a great deal of heat is evolved. It is crystallizable, less fusible than bismuth, and possesses the metallic lustre and a grayish-yellow colour.

When selenium is heated with bismuth, a crystalline selenide is formed of a silvery white colour.

260. *Experimental Illustrations.*

Bismuth and its oxide, exhibited. Its hue and habitudes with the blowpipe, compared with those of zinc, antimony, and arsenic.

SECTION IX.

OF IRON.

This metal is found abundantly in nature, principally in union with sulphur or oxygen.

Large masses of iron have been observed to fall to the earth at different times, and in various countries. Besides these metallic masses, a great number of stony bodies, called meteorolites, or aërolites, have fallen in like manner. In the latter, iron always exists both in the state of protoxide, and in that of metallic globules. The iron in these globules, and in the masses abovementioned, always contains nickel or cobalt, or both. Native metallic iron has also been found in small quantities, but does not contain nickel or cobalt. Iron is one of the most generally distributed substances in the creation, and, in the state of oxide, probably the most universal colouring matter.

Four species of ferruginous minerals are very abundant in nature; *magnetic oxides* and *sulphides*, and *sulphides* and *oxides* which are not *magnetic*.

Since ferruginous minerals, if not magnetic in the first instance, become so by exposure to the flame of the blowpipe, the magnet is a most useful test for iron.

of iron consist principally of the sesquioxide, or of a compound of this oxide with the protoxide, called the black or magnetic oxide. The means of extricating iron from its ores, will be mentioned in treating of the compounds of iron with carbon, which will on that account be treated of first.

Properties.—The mechanical properties of iron are too well known to need description. It is the most tenacious substance in nature, especially as steel, and the hardest among the malleable metals. Its ductility is greater than its malleability. Few metals are more easily oxidized by the joint agency of air and moisture. It is nearly as difficult to fuse as platinum. Its specific gravity is 7.788.

The equivalents of iron, and of its compounds with oxygen, chlorine, and sulphur, are as follows:—

Iron	- - -	- - - - -	28
Protoxide,	1 atom metal,	1 atom oxygen	36
Sesquioxide, or Red oxide,	2 atoms „	3 atoms „	80
Magnetic or Black oxide,	3 atoms „	4 atoms „	116
Or 1 atom protoxide and 1 atom sesquioxide			
Protochloride,	1 atom metal,	1 atom chlorine	64
Sesquichloride,	2 atoms „	3 atoms „	164
Protosulphide,	1 atom „	1 atom sulphur	44
Sesquisulphide,	2 atoms „	3 atoms „	104
Bisulphide,	1 atom „	2 atoms „	60

Remarkable Combustibility of Iron when minutely divided.

Iron in the pulverulent form, in which it is reduced from the sesquioxide by means of hydrogen, is liable to become ignited by the access of atmospheric oxygen, even after it has been completely refrigerated. This result is more likely to ensue, if a little alumina has been previously mixed with the oxide; since this prevents the union of the particles, and thus keeps them in that state of minute division which is favourable to the success of the experiment. I have found that the mass obtained from perfectly pure Prussian blue, will not ignite spontaneously, though consisting of iron and carbon in a state of minute division; but the presence of a small quantity of alumina, which enters into the composition of Prussian blue as usually prepared, is sufficient to qualify it for the formation of a pyrophorus.

Of the Compounds of Iron with Carbon, Boron, Silicon, and Phosphorus.

When ferruginous salts, containing carbon as a constituent, are exposed to heat without access of air, the iron and carbon are left in a state of combination in various proportions. Some of these carburets, that from the oxalate for instance, are liable to take fire when warmed in the air.

The process of evolving iron from its ores, comes under the fourth case of affinity, in which one body in excess, combines with two others previously united. The carbon with which the ore is ignited, combines both with the oxygen and metal, converting the one into a fusible carburet, called cast iron, the other into carbonic acid. The proportion of carbon in cast iron varies from 1 part in 25, to 1 in 15. In commerce, there are four varieties of cast iron; the *white*, the *black*, the *gray*, and the *mottled*. In the white, there is the least carbon, in the black, the most; and probably, in the other kinds, less than in the black, and more than in the white kind.

It should, however, be understood, that cast iron is probably never a pure carburet. Usually, it contains silicon and manganese, and frequently magnesium and phosphorus. This last mentioned element renders the iron less malleable at a high temperature. From cast iron, the malleable metal is extricated by exposure to heat and air; by which carbon, and silicon when present, are oxidized; the one being separated as a silicate of iron with the scoria, the other escaping as carbonic acid.

In some cases, malleable iron is obtained directly from the ore, by means of heat and charcoal.

Pure malleable iron is converted into steel, by being heated in contact with charcoal in ovens without access of air. The process is called *cementation*. By these means, iron acquires from $\frac{1}{50}$th to $\frac{1}{120}$th of its weight of carbon. The bars are blistered by the operation as they are seen in commerce. Broken up and welded, they form shear steel. Fused, they constitute cast steel.

It would appear that silicon is a frequent, if not a necessary ingredient in steel. According to Berzelius, the presence of manganese and phosphorus is essential to the formation of good steel. Damask steel is a peculiar species, which possesses the property of exhibiting waving lines on its surface, when acted on by an acid. It is alleged by Thenard, that some experiments which have recently been made, tend to prove that this is owing to the presence of two carburets of iron; one of which is blackened by the acid, while the other resists its action. I think it more probable, that the appearance in question is owing to a mixture of iron and steel. It has, however, been ascertained that a peculiar variety of this steel called *wootz*, which comes from India, contains aluminium, and may be imitated by the introduction, into steel, of a minute portion of that metal.

A silicuret, and probably a boruret of iron, may be obtained by heating iron with a mixture of charcoal and silicic or boric acid.

A phosphuret of iron is produced, when phosphate of iron is heated with lampblack. It resembles iron in colour, but is brittle, and fusible by the blowpipe.

Of the Compounds of Iron with Oxygen.

Iron forms two oxides, a protoxide and a sesquioxide; the former consisting of an atom of each constituent, the atter, of two atoms of metal, and three atoms of oxygen. Both these oxides act as bases.

The protoxide is formed during the solution of the metal in diluted sulphuric acid. The reaction which ensues under these circumstances, is always attended by the evolution of hydrogen, arising from the decomposition of the water in combination with the acid,* the oxidation of the metal, and the formation of a sulphate of the protoxide.

The protoxide, in union with the acid, forms a green solution, which, by evaporation, yields crystals of the same colour, known in pharmacy as green vitriol, or sulphate of iron. From a solution of this salt, the protoxide may be precipitated by an alkaline solution in the state of a white hydrate. From this hydrate the water cannot be expelled either by heat or desiccation, without causing the protoxide to acquire oxygen, either from the water in union with it, or from the air.

In consequence of this avidity for oxygen, solutions of this oxide become gradually more or less solutions of the sesquioxide; exchanging their grass green colour for that of red wine.

The protoxide appears to exist in chalybeate springs, and, in its nascent state, to be soluble in water; although I do not find that other chemists are aware of the fact. Its existence in them is ascribed usually to the presence of carbonic acid; but I have observed it in the water of the Yellow Springs, which gave no precipitate with lime-water.

We have only to make a pile of silver coin, alternated with disks of sheet iron, in a glass tumbler, supplied with water, in order to impart to the latter the property of chalybeate spring water. In the tumbler, as in those springs, the red oxide will soon be seen precipitating, and tinging, with its appropriate hue, both the liquid and the vessel.

---

* I infer that the atom of water, which, by a union with the anhydrous acid, constitutes the aqueous sulphuric acid of Berzelius, or in other words the acid of the shops of sp. gr. 1.850, acts as an oxybase. So that the result may be ascribed to the exchange of one radical for another; an atom of iron taking the place of an atom of hydrogen. Agreeably to this view of the subject, the aqueous acid should be regarded as a sulphate of hydrogen.

As light promotes the further oxidation and consequent precipitation of the iron, the solution of the protoxide, by the means which I have described, will be more permanent in an opake vessel.

There does not appear to be any mode in which the protoxide of iron can be isolated.

The sesquioxide, or peroxide of iron, also called the red oxide from its colour, which is of a dingy blood-red, exists in nature in great abundance, forming, sometimes, large beds or masses, at other times, botryoidal, or mammillary concretions.

Ochres consist of alumina, mixed with the sesquioxide of iron, either uncombined with water, or in the state of hydrate.

The sesquioxide, as we have already stated, is spontaneously produced by the absorption of oxygen by the protoxide, when exposed to the air. In fact, by the addition of nitric acid to any ferruginous solution, the iron becomes more or less sesquioxidized. On the other hand, it may be partially deoxidized, and restored to the state of protoxide, by digestion with iron filings, or by the addition of the protochloride of tin. Hence the addition of this chloride to ink destroys the colour, by reducing the iron to the state of protoxide, which, with gallic and tannic acid* (tannin), forms a compound comparatively colourless.

When a solution of the chloride of gold is added to a solution of the protoxide of iron, the gold probably relinquishes its chlorine to one portion of the iron in the protoxide. The oxygen, consequently displaced, sesquioxidizes another portion of the iron; so that metallic gold precipitates, and the chloride and oxide of iron, combining in the state of an oxychloride, remain in solution.

The destructive distillation of nitrate or sulphate of iron evolves the sesquioxide. It has been stated, in treating of sulphuric acid, that it was originally obtained by these means from copperas or green vitriol, the sulphate of the protoxide of iron. The oxide which remains after the expulsion of the acid, has long been known under the ne of *colcothar of vitriol.* To render it free from all ıains of acid, it should be washed with water.

---

* As I concur with Berzelius in considering tannin an acid, it would be inconsistent not to give it the appropriate appellation of *tannic acid.*

The protoxide and sesquioxide of iron combine in va- ıs proportions. The scales, called *finery cinder*, which off during the forging of incandescent iron, consist of toxide and sesquioxide. The oxide formed by subject- iron at a red heat to steam, is the *black oxide*, com- ed of one atom of protoxide and one of sesquioxide.

The native magnetic oxide of the mineralogists, is, ac- ding to Thenard, the same as that obtained when iron ıxidized by steam.

The same author alleges that neither the hydrate o protoxide nor sesquioxide are magnetic; this quality ıg exhibited only when the two oxides are associated he proportion of one atom of protoxide to one of ses- ɔxide.

Of the Reaction of Iron with Acids.

The reaction of iron with sulphuric acid when hot and centrated, is quite analogous to that already described taking place between that acid, and mercury, copper, l, &c. The reaction of iron with this acid when dilute, been mentioned and explained above.

n its habitudes with nitric acid, iron resembles tin and nuth. If the acid employed be concentrated, and the ı minutely divided, an explosion sometimes ensues.

Vith gallic and tannic acids, as existing in the in- on of galls, the sesquioxide of iron produces a purple ılack colour, in other words, ink. With succinic acid sesquioxide yields a brown precipitate, with benzoic l, an olive coloured precipitate, and with meconic and ıhocyanhydric acid, a blood-red colour.

There seems, however, to be some obscurity respect- ink. The colour of this useful liquid is ascribed to ı acids; but we are not informed whether it could be le with either alone, and if so, with which the best; f both are requisite, in what proportions they should ɔresent.

Of the Compounds of Iron with the Halogen Class.

Chlorine forms with iron a protochloride and sesqui- ɔride, which correspond in composition with the oxides. The anhydrous protochloride may be obtained by passing chlorohydric acid gas over iron filings heated to redness in a glass tube. The hydrated protochloride may be procured by the action of liquid chlorohydric acid on iron filings. The protochloride, in its anhydrous state, is of a pale green colour, astringent, crystallizable, very soluble in water, and volatilizable by heat. When exposed to the action of the air, it absorbs oxygen, and forms an oxychloride, consisting of the sesquioxide, and sesquichloride.

The hydrated sesquichloride of iron is produced, when the sesquioxide of iron is exposed to the action of chlorohydric acid. It may be obtained in the anhydrous state by heating iron filings in an excess of chlorine. Thus obtained, it is volatile and deliquescent.

Bromine and iodine form compounds with iron, which no doubt correspond in composition with its oxides and chlorides.

There are two fluorides of iron which act either as acids or bases.

The protocyanide of iron is formed by exposing the cyanoferrite of ammonium, which is a compound of the cyanides of iron and ammonium, to heat in a retort. The cyanide of ammonium, which is volatile, passes over, leaving the protocyanide of iron in the form of a grayish-yellow powder. This cyanide acts as a powerful cyanacid, combining in that capacity with the cyanides of almost all the metals. It also combines with cyanhydric acid, but whether as an acid or a base, appears to me doubtful. I incline to the opinion that it acts as an acid, forming a cyanoferrite of the cyanobase of hydrogen.

The sesquicyanide of iron is obtained by mingling a solution of the fluosilicate of the fluobase of iron with a solution of the cyanoferrite of potassium. A fluosilicate of the fluobase of potassium precipitates, and the sesquicyanide of iron remains dissolved. Its solution is of a deep brownish-yellow colour, and an astringent taste. If we attempt to obtain it in the solid form by desiccation, it is partially decomposed, and converted into Prussian blue.

When the cyanide of potassium is mingled in solution with a ferruginous salt, a precipitate ensues, well known under the name of Prussian blue, having been first accidentally discovered at Berlin. It would seem that to perfect the colour of this precipitate, both oxides of iron should be present; so that the protoxide may produce the protocyanide, and the sesquioxide the sesquicyanide. These cyanides, by their union, form the compound in question.[*]

---

[*] Berzelius designates Prussian blue as the *cyanure ferroso-ferrique*, being one of his double salts. It has been mentioned that when potash is digested in water with Prussian blue, a yellow crystalline salt results, which I call *cyanoferrite of potassium*. In fact the cyanogen of the sesquicyanide of iron, and the oxygen of the potash exchange places; so that a cyanide of potassium and oxide of iron are produced. With the former the protocyanide of iron combines, forming another double salt according to the Berzelian nomenclature, but according to that which I adopt, a cyanoferrite of the cyanobase of potassium. In the last mentioned state of combination, agreeably to my definition of acidity, the protocyanide acts as an acid; [illegible]ce I have called it *cyanoferrous acid*. It seems questionable whether, while

Of the Compounds of Iron with Sulphur and Selenium.

Iron forms with sulphur a protosulphide, a sesquisulphide, and a bisulphide. Moreover the protosulphide combines in various proportions with the bisulphide or with the metal.

A hydrated protosulphide is alleged to be formed during the combustion which arises from triturating with moisture two parts of iron filings with one and a half of sulphur. This hydrated protosulphide is liable to absorb oxygen with a rapidity so great as to produce ignition. Owing to this property, its presence in bituminous coal beds sometimes causes them to take fire spontaneously.

Native protosulphide of iron is of rare occurrence; but the magnetic and bisulphides are abundantly found in nature, especially the latter, which is one of the most common minerals. From its resemblance to gold, it is frequently mistaken for that metal by inexperienced observers. When intensely heated, a portion of its sulphur sublimes; and hence it is one of the sources of that important substance.

It is alleged by Thenard that there are two varieties of the bisulphide, which, though identical in composition, are dissimilar in their crystalline form and in their properties. Of these varieties only one is susceptible of spontaneous reaction with air and moisture, and consequent conversion into a sulphate. To a similar transformation of this and other sulphides, we are indebted for the greater part of the green vitriol, or sulphate of iron, used in the arts. Beds of these minerals, in a state of spontaneous decomposition, are to be met with in every country.

By exposure to a current of sulphydric acid, the sesquioxide of iron is converted into the sesquisulphide, provided the temperature be not above 212°. At a higher temperature a bisulphide results.

According to Thenard, one of the compounds, formed by the union of the protosulphide and bisulphide, constitutes the mineral called ***magnetic pyrites***. It is also formed, as he alleges, when iron in a state of intense ignition is presented to sulphur, and when either the sesquisulphide or bisulphide is fused. In fact it would seem that he considers none of the other sulphides as magnetic; although the presence of a greater proportion of iron in the protosulphide would lead us to suspect in it a greater susceptibility of magnetic influence. Berzelius, however, considers the protosulphide as magnetic.

The selenide of iron is formed by causing the vapour of selenium to pass over iron filings heated in a glass tube. It has a metallic brilliancy, and a deep gray colour approaching to yellow.

261. *Experimental Illustrations.*

Iron, dissolved by chlorohydric and sulphuric acid. Red and magnetic oxide of iron, exhibited; and their so-

in combination with the sesquicyanide of iron, this protocyanide can be consid as acting as an acid; more especially as the sesquicyanide also combines wit cyanide of potassium, and has, therefore, claims to be considered as *cyanoferri* However I think it would on the whole be most consistent to allow the name I have given to the protocyanide when in union with the cyanide of potassi follow it into its combination with the sesquicyanide of iron, wh the present it were better to designate as *Prussian blue*, rather *iron.*

lutions, precipitated by galls, and by cyanoferrite of potassium. Effects of protochloride of tin on the colour of the precipitates. Ores of iron, rendered magnetic by the blowpipe.

◆

SECTION X.

OF ZINC.

This metal exists in nature in four states; in that of sulphate, silicate, carbonate, and sulphide. As a silicate or carbonate, it is known in mineralogy under the name of *calamine;* its sulphide is called *blende.*

The metal is obtained from calamine by heating it with charcoal. It may be purified by distillation.

Properties.—Zinc is of a brilliant metallic white colour, slightly tinged with the hue of lead. Its structure is strikingly crystalline. Its specific gravity is about 6.86. Under ordinary circumstances it is not malleable, but may be laminated by rollers at a heat somewhat above that of boiling water. It melts at about 680°, volatilizes at a higher temperature, and may be distilled by being intensely heated in a stoneware retort. By exposure to the atmosphere it is slightly oxidized, but at a white heat burns rapidly with intense light, the resulting oxide being volatilized in fumes. Water is rapidly decomposed when passed in the state of steam over ignited zinc, or when presented to it together with a due proportion of sulphuric or chlorohydric acid. Zinc combines with carbon and phosphorus.

The equivalents of zinc, and of its compounds with oxygen, chlorine, and sulphur, are as follows:—

Zinc,	- -	- -	- -		32
Protoxide,	1 atom	metal,	1 oxygen,		40
Peroxide, doubtful.					
Chloride,	1	„	„	1 chlorine,	68
Sulphide,	1	„	„	1 sulphur,	48

Of the Compounds of Zinc with Oxygen.

The protoxide of zinc is formed during the combustion of the metal in atmospheric air. From the lightness and fleeciness of its texture, when obtained in this way, it was formerly called nihil album, and lana philosophica. The protoxide may be obtained from one variety of the ore called calamine, by heating it to expel carbonic acid. To prepare it as it is presented to us in the shops, the ore is roasted, pulverized, and levigated. A better process, as I conceive, is that of collecting the woolly matter produced by the combustion of the metal. But to either of these modes I should prefer that of precipitating the oxide from the sulphate in solution, by liquid ammonia.

The peroxide is obtained by the same means as the superoxide of copper, which it resembles in many of its properties. The protoxide usually acts as a base, though in some cases it may act feebly as an acid. The peroxide performs the part neither of a base nor of an acid.

The action of sulphuric acid on zinc is similar to that of the same acid on iron. When subjected to nitric acid, zinc takes all the oxygen from one portion of the acid, while the protoxide thus formed is dissolved by another portion; meanwhile the nitrogen escapes with violent effervescence. Professor Emmet has recommended the reaction of this metal with the nitric acid in nitrate of ammonia, as an excellent method of procuring pure nitrogen.

If the solution of acetate of zinc, obtained by the reciprocal decomposition of the acetate of lead and sulphate of zinc, page 136, be clarified by subsidence or filtration, and then evaporated, the acetate of zinc may be obtained in the crystalline form. It will also be in a state of purity, if the materials have been used in the equivalent proportions, or with a slight excess of the acetate of lead. Pure acetate of zinc may also be obtained by the process for forming the arbor Saturni; as in that process, after a sufficient time, the lead is completely displaced by the zinc, which remains in solution.

The acetate of zinc is also obtained, agreeably to one of the formulas of the Pharmacopœias, as a tincture, in other words, in alcoholic solution, by subjecting a mixture of sulphate of zinc and acetate of potash, in equivalent proportions, to alcohol. The mixture of the salts is followed by a reciprocal decomposition, analogous to that produced by the mixture of sulphate of zinc, and acetate of lead; excepting that the resulting sulphate of lead is quite insoluble in water, and separates by precipitation; while, in the other case, both of the resulting salts, being more or less soluble in water, alcohol is employed to separate them. This liquid does not dissolve the sulphate of potash, while it readily takes up the acetate of zinc.

Of the Compounds of Zinc with the Halogen Class.

Anhydrous chloride of zinc is formed during the combustion of zinc in chlorine. It was formerly called the *butter of zinc* from its consistency. It is of a grayish-white colour, translucid, astringent, fusible at the temperature of boiling water, and volatilizable at a red heat. By dissolving zinc filings in chlorohydric acid, and evaporating the solution to dryness, we may obtain this chloride in the state of hydrate.

Zinc combines with iodine, fluorine, and cyanogen. The cyanide acts as an acid, the fluoride both as a base and an acid.

Of the Compounds of Zinc with Sulphur and Selenium.

Sulphide of zinc may be obtained by heating the sulphate to whiteness with a carbonaceous paste. It is difficult to combine zinc directly with sulphur; but when the vapour of sulphur is passed over incandescent zinc, a combination takes place with a violent commotion, and the evolution of so much heat as to volatilize part of the zinc. The same result ensues when zinc filings are suddenly and intensely heated with the persulphide of potassium, or the powdered bisulphide of mercury.

Sulphide of zinc is solid, yellow, tasteless, less fusible than zinc, indecomposable by heat alone, but reducible by intense ignition with charcoal. It is a powerful sulphobase.

When the sulphate of zinc is decomposed at a low red heat by hydrogen, an oxysulphide, or in other words a compound of the sulphide and oxide, is formed.

When the vapour of selenium is passed over zinc heated to redness, the union of the two substances takes place with violence, being attended with the phenomena of active combustion. The resulting selenide is a yellow powder.

262. *Experimental Illustrations.*

Zinc, subjected to diluted sulphuric, and diluted chlorohydric acid. Arbor Saturni, produced by it in a solution of acetate of lead. Combustion of the metal in an incandescent crucible. Its habitudes with the blowpipe, exhibited. Reaction of zinc filings and bisulphide of mercury; also of the melted metal with a fused nitrate.

SECTION XI.

OF ARSENIC.

This metal is found in nature, in combination with oxygen, sulphur, and various metals. It is sold in commerce under the name of cobalt, and in the state in which it bears this name, it is full of crevices, and so much tarnished or blackened by oxidizement, both internally and externally, that it is not possible, even by a fresh fracture, to see the true colour and lustre of the metal.

In order to attain this object, the cobalt (as it is absurdly named) should be coarsely pulverized, and introduced into a glass tube sealed at one end. The tube should be less than half full. Thus prepared, it should be placed within a cylinder of iron, closed at the base. The but-end of a gun barrel will answer. The space between the iron and the glass should be filled with sand, and another gun barrel applied, so as to receive any fumes which may arise, and conduct them into a chimney. That portion of the glass tube which contains the arsenic, should be kept red-hot for about half an hour. After the apparatus is quite cool, the metal will be found in crystals of great splendour, occupying that portion of the glass tube which is next the part heated to redness.

Properties.—Exposed before the blowpipe, arsenic is distinguished by burning before it fuses, and by emitting copious white fumes, which have the odour of garlic. These fumes are easily produced, by projecting a portion of the metal upon a hot iron, or by subjecting it in any other way to heat and air. They are evolved on a large scale during some metallurgic operations, and, after being subjected to a subsequent distillation, constitute the arsenious acid or white arsenic of the shops. This metal is extremely brittle, and, when newly sublimed, has the colour and brilliancy of polished steel. It requires less heat to vaporize than to fuse it; so that it cannot be melted without the aid of a pressure greater than that of the atmosphere. Thenard alleges that it may be sublimed in a retort filled with nitrogen, at the temperature of 356°. I am under the impression, that the nitrogen must co-operate as a solvent in this result; taking up the metal in the warmer part of the retort, and depositing it in the colder part. I have ascertained that metallic arsenic, situated in a glass tube immersed in melted lead, is not volatilized, unless so far as it may be oxidized; and, moreover, in my efforts to obtain the arsenical ring, I have remarked that it is formed just beyond the part of the tube which is reddened by the heat.

The following table gives the equivalents of arsenic, and of its compounds with oxygen, chlorine, and sulphur.

Arsenic,	- -	- - -	38
Suboxide, doubtful.			
Arsenious acid,	2 atoms metal,	3 atoms oxygen,	100
Arsenic acid,	2 atoms ,,	5 atoms ,,	116
Protochloride,	1 atom ,,	1 atom chlorine,	74
Sesquichloride,	2 atoms ,,	3 atoms ,,	184
Protosulphide,	1 atom ,,	1 atom sulphur,	54
Sesquisulphide,	2 atoms ,,	3 atoms ,,	124
Persulphide,	2 atoms ,,	5 atoms ,,	156

Of the Compounds of Arsenic with Oxygen.

According to Berzelius, the black matter which obscures the brilliancy of metallic arsenic on exposure to the air, is a suboxide. Thenard seems inclined to consider it as a protoxide; while by other chemists it is treated as a mixture of arsenious acid and the metal; as, when exposed to heat or to acids, it yields arsenious acid, and metallic arsenic. But as it appears that arsenious acid is a compound of oxygen and the metal, in the ratio of three atoms of the former to two of the latter, it would be reasonable to infer the existence of a compound consisting of an atom of each. Besides, it has been ascertained by Berzelius, that the exposure of arsenic to air never causes an absorption of more than eight per cent. of oxygen; whereas, to form arsenious acid, the metal must absorb thirty-two per cent. Now it seems very improbable that, under the same circumstances, one portion of the metal should absorb thirty-two per cent. of oxygen, while another portion should absorb none.

Arsenious acid is formed when arsenic is ignited in the air. It is milk-white, has a rough and slightly acid taste, followed by a flavour feebly sweet. When heated in open vessels to a low red heat, it softens, sublimes, and condenses in the form of a white powder, or, when the vessels are large and the operation slow, in regular octohedral crystals.

Arsenious acid is soluble in water, but not to any great extent. Berzelius states that a saturated solution of it in boiling water, in which the deposition of crystals has commenced, contains but a twelfth or thirteenth of its weight. There is much uncertainty, and some mystery, respecting the extent of its solubility in cold water. Berzelius quotes an observation made by Fischer, that the portion employed is never entirely dissolved; and that as the ratio of the water to the acid increases, this being always in excess, the quantity dissolved lessens. Thus 80 parts of the former take up $\frac{1}{90}$th of its weight; 160 parts, $\frac{1}{180}$th; 240 parts, $\frac{1}{280}$th; and 1000 parts, only $\frac{1}{1200}$th. Arsenious acid, when subjected in close vessels to a heat approaching to redness, fuses into a transparent glass of the specific gravity of 3.699, unchangeable in dry air, but gradually becoming white and opake in a humid atmosphere.

In the last mentioned state, it appears to be more soluble in boiling water, and to be retained in solution to a greater extent than in the transparent state. The transparent acid reddens litmus; while, by the opake, litmus previously reddened may be restored to its original colour.

These varieties of arsenious acid are, therefore, considered as isomeric.

Arsenious acid is a most virulent poison. It is found in nature, both in the crystalline form, and in that of a white powder. By digestion in aqua regia or in strong nitric acid, evaporation of the resulting solution to dryness, and subsequent ignition nearly to redness in a platinum crucible, arsenious acid acquires two additional atoms of oxygen; so that a compound is formed in which the metal is to the oxygen, in the proportion of two atoms to five. This compound is arsenic acid.

Arsenic acid is solid, white, and caustic; it reddens litmus paper. When exposed to heat it melts into a glass; but if the heat be pushed to redness, it is decomposed into arsenious acid and oxygen gas. This is a more powerful acid, a more virulent poison, and more energetic in its affinities, than arsenious acid. Like other fixed* acids, it expels, when aided by heat, the volatile acids from their combinations. It forms, with certain metallic oxides, salts which crystallize in the same form as the corresponding phosphates; whence, as I have elsewhere stated, arsenic and phosphoric acid are said to be isomorphous. Of such bodies, one may be substituted for the other in crystalline compounds, without altering the form of the resulting crystals.

---

* The word *fixed* is employed by chemists to conve[illegible] of a body which will bear a high temperature without decomposition o[illegible]

Arsenic acid is deliquescent, and much more soluble than arsenious acid; yet after being vitrified by heat, it does not dissolve completely at first, but deposites a white powder, which, by frequent stirring, finally dissolves. In consequence of this, and some other differences in their properties, it has been supposed that the melted and unmelted arsenic acids are isomeric with regard to each other.

Arsenious and arsenic acid severally combine with the metallic oxides. Arseniate of potash is formed, when arsenious acid is deflagrated with nitrate of potash. Fowler's solution, the *liquor potassæ arsenitis* of the U. S. Pharmacopœia, is made by boiling arsenious acid and carbonate of potash, of each 64 grains, with a pint of distilled water, and adding four fluidrachms of the spirit of lavender. The arsenious acid, displacing the carbonic acid, forms with the alkali an arsenite of potash. This solution produces a yellow precipitate with nitrate of silver, without the aid of ammonia, as the place of this base is supplied by the potash.

The soluble arsenites and arseniates yield precipitates with solutions of copper and silver, and destroy the blue colour of the iodide of starch. In the instances of copper and silver, an arsenite or arseniate of those metals is formed. The arsenite of copper is of an apple-green colour, and forms a pigment called *Scheele's green*. The arsenite of silver is yellow; the arseniate, brick-red.

When cold, sulphuric acid does not react with arsenic; but when warm, the acid is decomposed, and arsenious acid formed.

The reaction of nitric acid with arsenic is similar to the reaction of sulphuric acid with the same metal; except that it takes place without the aid of heat, and that the arsenious acid which is at first produced, is finally converted into arsenic acid.

Of the Compounds of Arsenic with the Halogen Class.

By the direct reaction of chlorine with arsenic, or by the distillation of this metal with the bichloride of mercury, a sesquichloride of arsenic is obtained. If, in this process, the protochloride of mercury be substituted for the other, a protochloride is generated: and by the reaction of the metal with an excess of chlorine, a perchloride is alleged to result.

The sesquichloride is a colourless fuming liquid, of an oleaginous consistency, quite analogous, both as to the means of evolution and its properties, to the bichloride of tin, or fuming liquor of Libavius.

Bromine and iodine severally form compounds with arsenic, which correspond in composition with the sesquichloride.

The fluoride of arsenic is a colourless fuming liquid, which probably consists of two atoms of arsenic, and three of fluorine.

Of the Compounds of Arsenic with Sulphur and Selenium.

There is scarcely any limit to the number of proportions in which arsenic and sulphur appear to combine; yet Berzelius admits the existence of but five distinct sulphides, and Thenard recognises only three,—a protosulphide, a sesquisulphide, and a persulphide. By the union of these with various quantities of the metal, or of sulphur, all the other compounds are supposed to be produced.

The proto, sesqui, and persulphide severally combine with sulphobases, as sulphacids.

The protosulphide of arsenic, known in commerce by the name of *realgar*, may be obtained by heating a mixture of two parts of sulphur, and rather less than three and a half parts of arsenic. It is procured in the large way by distilling arsenious acid with sulphur. It is tasteless, crystallizable, less fusible than arsenic, and of an orange-red colour. When heated in close vessels it volatilizes unchanged, but if the air be admitted it is converted into arsenious and sulphurous acid. It is found native.

The sesquisulphide is obtained by adding chlorohydric acid to a mixed solution of sulphide of potassium and arsenite of potash. The oxygen of the arsenious acid and of the potash unites with the hydrogen of the chlorohydric acid, the chlorine with the potassium, and the sulphur with the arsenic. The chloride of potassium remains in solution, while the arsenic and sulphur precipitate in the state of sesquisulphide, and in the form of beautiful yellow flocks.

The sesquisulphide is found in nature, and is known in commerce under the name of *orpiment*. It is crystallizable. When heated gently in close vessels it melts, and if the heat be further elevated volatilizes, and may be condensed unchanged. If the access of air be permitted during the operation, sulphurous and arsenious acid are formed.

The persulphide of arsenic is formed by passing sulphydric acid gas through a solution of arsenic acid in water. It is yellow, and resembles orpiment. It is fusible, volatilizable, and capable of reddening litmus.

When arsenic is dropped into selenium, previously liquefied by heat, a selenide is produced. If this selenide be subjected to distillation at a red heat, a perselenide is obtained.

Of the Compounds of Arsenic with Phosphorus and Hydrogen.

A phosphuret of arsenic may be formed by heating phosphorus with the metal. It is black and brilliant.

If the experiment of the philosophical candle be repeated, some powdered arsenic being intermingled with the usual materials, the hydrogen, in its nascent state, will unite with the arsenic, forming arseniuretted hydrogen. Hence the gaseous jet, when ignited, will produce a flame of a dismal, pale, bluish-white colour, giving rise to arsenical fumes, and the characteristic odour of arsenic. A more accurate process for generating this gas, is to dissolve an alloy of tin and arsenic in chlorohydric acid.

If a mixture of two parts of sulphide of antimony, two of bitartrate of potash, and one of arsenious acid, be kept at a red heat in a covered crucible, an alloy may be obtained, which will evolve arseniuretted hydrogen as soon as moistened. To obtain arseniuretted hydrogen, it is only necessary to introduce a small portion of this alloy into a bell glass, inverted over fresh boiled water, as usual in pneumato-chemical processes. The gas is gradually evolved, and of course collected in the bell glass.

Arseniuretted hydrogen is highly inflammable, in common with all other aëriform compounds of hydrogen. It is extremely deleterious to life, being injurious when liberated in quantities too small to be immediately annoying to the operator. It is productive of nausea and vomiting, sometimes of constipation, sometimes of purging. As palliatives of these symptoms, Berzelius recommends warm tea, and sulphydric acid gas.

Though at ordinary temperatures a permanent gas, arseniuretted hydrogen at 40° condenses into a liquid. A ten-thousandth part of this gas ay be detected in a gaseous mixture, by the metallic pellicle which it uses upon a solution of corrosive sublimate.

Oil of turpentine appears to form a crystalline compound, by reacting ith arseniuretted hydrogen.

A solid compound of arsenic with hydrogen has been made, by sub-ecting an alloy of potassium and arsenic to water; and likewise by the ecomposition of water by the Voltaic series, one of the wires, employed or the purpose, terminating in a piece of arsenic immersed in that iquid.

263. *Experimental Illustrations.*

Appearance and habitudes of arsenic, in its metallic and crystalline form, contrasted with those of zinc, antimony, and bismuth. Arsenious acid and its solutions, exhibited: also, Fowler's solution, or solution of arsenite of potash. Arsenious and arsenic acid, in solution, added to large vessels of clear water, and detected by sulphydric acid, or by ammoniacal nitrate of silver or copper. Same acids precipitated by lime-water. Exhibition of Scheele's green, or arsenite of copper. Combustion of arseniuretted hydrogen, displayed.

Of the Means of detecting Arsenic, in Cases where poisoning is suspected by it.

In respect to arsenic, the most important subject of attention is the means of detecting this metal, in cases in which it may be used as a poison.

The first steps are of course directed to the collection and preservation of all the matter which may have come from the patient in vomiting, or which may be obtained by opening the stomach. As it is usually in the solid state of arsenious acid that this poison is administered; both the matter thus obtained, and the surface of the stomach should be rigidly examined, in order to detect any particles which may remain in that state. Berzelius counsels us especially to scrutinize those spots in the stomach which appear to have been inflamed, in order to ascertain whether any particles of the poison are lodged in them.

In the next place, the whole mass, collected and preserved as above advised, should be thrown into water, which, while stirred to cause the suspension in it of the lighter portions of the matter, should be poured off, together with that lighter matter from the heavier subsiding portion. The liquid thus separated should be filtered; and both the resulting filtered solution, and the heavier matter which may have sunk to the bottom of the vessel, should be evaporated to dryness in an appropriate oven, or in a vessel kept hot by boiling water. The whole being quite dry, it should be introduced into a glass or porcelain vessel; and, adding a sufficient quantity of strong nitric acid to cover the mass, it should be subjected to a heat adequate to cause a brisk reaction. This should, if necessary, be sustained by further additions of the acid, until there is no longer any organic matter undecomposed.

As nitric acid can have no other effect upon arsenic than that of converting it into arsenic acid, in which state it is less volatile than in any other; this process tends at the same time to annihilate the organic impurities, and to secure the metal. Thus the matter to be assayed is much diminished in bulk, and if it contain arsenic must hold it as arsenic acid, which is more soluble than arsenious acid. Hence, if the dry mass be digested with water, a solution will be obtained, which, being filtered, may be precipitated by lime-water. The arseniate of lime which precipitates, being dried, should be mingled with about one-fourth of its weight of powdered charcoal, and introduced into a glass tube, sealed at one end. The mixture having been made to settle down to the sealed end within as narrow limits as possible, a little cotton wick must be fastened to the end of a wire, by twisting the wire so as to form one end into an eye, and passing the wick through the eye, and winding it about the end of the wire, until a plug of cotton be made just large enough to slide in the tube like a piston. For greater security, the wick may be wound about the wire, so that one end may be held in the hand. By means of the piston, thus formed, the portion of the tube, not occupied by the mixture, may be wiped clean. The tube should now be subjected to the flame of a spirit lamp, the piston being retained in it, as near the mixture as it can be without being injured by the heat. The heat should be applied at first to the anterior part of the mass, proceeding to the posterior part afterwards; and as soon as the whole ceases to give out aqueous vapour, the piston should be passed quickly down, so as to wipe away the moisture condensed, together with any accompanying foulness. The piston being again beyond the reach of the heat, the part of the tube containing the mixture should, by the aid of a blowpipe, be exposed to a temperature as high as the glass will bear. If there be arsenic in the mixture, it will now appear in a bright metallic ring, just beyond that part of the tube which was heated red-hot. On cutting the tube at the part where the ring appears, and heating it by a spirit lamp, the alliaceous smell of arsenic will be perceived, if this metal be present; and the same smell will be experienced on igniting the cotton of the piston above mentioned.

The process thus described is that which I employed in the analysis of some matter sent to me from Westchester by Dr. Thomas; having been obtained from the stomach of a woman poisoned by her husband. I afterwards repeated it successfully at Westchester, in presence of Dr. Thomas and another physician; and upon their evidence of the result so obtained, the murderer was convicted. Before his execution he confessed himself to be guilty.

Where no arsenic can be detected in the contents of the stomach, it may be found in the membranes, or coats. Hence, in making the examination for arsenic, the stomach should be boiled in nitric acid, until all the organic matter is destroyed.

Very minute quantities of arsenic may be detected by the aid of silver or copper in solution. With silver, arsenic acid gives a brick-red, arsenious acid, a yellow precipitate. With copper, arsenious acid produces a very striking green precipitate of arsenite of copper, called Scheele's green. Sulphydric acid gas produces, with either acid, a yellow precipitate of sulphide of arsenic. As these results are precarious, and liable to be produced by other causes, they should not be considered as conclusive evidence.

In the case of the murder above mentioned, I found that the arsenic acid, as procured from the contents of the stomach, would not assume the appropriate hue in precipitating with silver, whether before or after its union with lime. Instead of a brick-red, it was of a muddy colour. By Dr. Feutchwanger, who was present during many of my experiments, this was ascribed, correctly as I believe, to phosphoric acid. It has been stated, that it is difficult to separate these acids when associated, from their isomorphism, or, in other words, crystallizing in the same form.

By simple affinity, neither arsenious nor arsenic acid can be precipitated by the soluble salts of silver or copper. Hence an alkali must be present, either in union with the arsenical acids, or with the metallic salt. This object is attained conveniently, by the addition of ammonia to the nitrate of silver or copper; as, with either of those metals, that alkali forms a soluble ammoniacal nitrate.

264. *Experimental Illustrations.*

Small portions of arsenious acid, or of the arseniate of lime, mingled with powdered charcoal, and subjected to heat in a glass tube. Arsenical ring, produced and exhibited.

◆

SECTION XII.

OF ANTIMONY.

Antimony sometimes occurs in nature in the metallic state or in that of oxide, and exists abundantly as a sulphide. It is in fact the sulphide that is called antimony in commerce, the metal being designated as the *regulus* of antimony.

The ores of this metal had been known for a long time; but for its extraction from them, the world is indebted to Basil Valentine, who lived towards the close of the fifteenth century. Since that period, from its utility in medicine, it has been eminently an object of investigation.

Metallic antimony may be obtained by mingling the sulphide with two-thirds of its weight of bitartrate of potash, and one-third of its weight of nitre, and deflagrating the mixture in a red-hot crucible. The oxygen of the nitre converts the sulphur into sulphurous acid, which escapes; while the alkali of both the salts operates as a flux, or in other words promotes the fusion of the mass. The carbon of the tartaric acid counteracts the oxidizement of the metal.

Charcoal, intimately intermingled with carbonate of potash or soda, may be used instead of the bitartrate.

Antimony thus obtained is not quite pure. To render it so it may be dissolved in aqua regia, precipitated in the state of oxychloride by water, and revived by ignition with bitartrate of potash.

Properties.—Antimony is so brittle as to be easily pulverized. It displays a crystalline structure, and may be crystallized by the process resorted to in the case of sulphur. When quite pure and newly fractured, it is of a silver-white colour, and very brilliant. If it be rubbed between the fingers, they acquire a perceptible odour. Its specific gravity is 6.7. It fuses a little below a red heat. When thrown in a state of fusion upon a board, it produces a beautiful effect, being dispersed into a multitude of ignited globules, which emit copious fumes of oxide, and leave their traces upon the board. The temperature of the globules seems to be supported by their own combustion.

According to Berzelius, the purity of antimony is indicated by a silvery whiteness, and a granular or fine lamellar texture; whereas the metal otherwise does not excel tin in whiteness, and is coarsely lamellar, almost as if susceptible of cleavage.*

The equivalents of antimony, and of its compounds with oxygen, chlorine, and sulphur, are as follows:—

Antimony,	-	-	-	-	-	64
Sesquioxide,	2	atoms	metal,	3	oxygen,	152
Antimonious acid,	2	„	„	4	„	160
Antimonic acid,	2	„	„	5	„	168
Sesquichloride,	2	„	„	3	chlorine,	236
Bichloride,	2	„	„	4	„	272
Perchloride,	2	„	„	5	„	308
Sesquisulphide,	2	„	„	3	sulphur,	176
Bisulphide,	2	„	„	4	„	192
Persulphide,	2	„	„	5	„	208

---

* It appears to me that the differences here referred to, are dependent, as in other cases, on slowness or quickness of cooling. A button which was granular when taken from a crucible refrigerated in water,—by fusion in an iron mortar in which it was prevented from cooling quickly by proximity to a fire, acquired a lamellar texture. Bad antimony looks like hornblende rock when broken, as to its crystalline texture, and cannot be fused into a globule as liquid or pure. It will not answer as well for the experiment of throwing on the board, as the pure metal.

Of the Compounds of Antimony with Oxygen.

Sesquioxide of antimony may be obtained by exposing the metal to heat with access of air; by moderately roasting the sulphide; or by subjecting the sesquichloride to water, in which case a powder precipitates, called *powder of Algaroth*, from the name of the physician who first recommended it to public attention. This powder, being an *oxychloride*, by digestion with the carbonate of potash, is converted into the sesquioxide.

It may also be obtained by the reaction of the metal with diluted nitric acid, afterwards repeatedly digesting the resulting subsalt in water, until this liquid no longer reddens litmus.

In the form in which the sesquioxide is obtained by heat and air, it received formerly the name of *argentine flowers of antimony.*

When obtained from the oxychloride, the sesquioxide has a tinge of gray. If the sesquioxide, as procured by the last mentioned method, be heated, it takes fire, and is converted into antimonious acid. The sesquioxide acts feebly both as an acid and a base. Combined with bitartrate of potash, it constitutes tartar emetic, and is the only compound of antimony with oxygen, which is considered as medicinal.

Antimonious acid is generated by digesting antimony in nitric acid, evaporating the liquid to dryness, and calcining the residue; or by thoroughly roasting the sulphide of antimony with access of air. Antimonious acid is white, tasteless, infusible, fixed, indecomposable by heat, and insoluble in water.

When nitric acid is added to a solution of the antimonite of potash, the antimonious acid is precipitated in the state of hydrate. In this state it reddens litmus paper.

Anhydrous antimonic acid is obtained by subjecting the oxychloride to the action of nitric acid, and afterwards exposing the resulting mass to a temperature of 500° or 600°, to expel any excess of this acid. By deflagrating the metal with four times its weight of nitre, dissolving in water the resulting mass, and afterwards adding nitric acid, which combines with the alkali, *hydrous antimonic acid* is procured.

Anhydrous antimonic acid is yellow, tasteless, and insoluble in water. When hydrous, it is white, and has the property of reddening litmus.

Just at the moment when certain antimonites and antimoniates, subjected to a low red heat, lose their water of crystallization, they give rise to a transient light, as vivid as would result from a true combustion. Yet they incur in consequence no change in weight. Their colour is rendered brighter, and they become less susceptible of decomposition by acids. This result ensues especially with the antimoniates of copper, cobalt, and zinc.

Sulphuric acid, when cold or diluted, does not react with antimony, but, when warm and concentrated, is partially decomposed, evolving sulphurous acid, and forming a sesquioxide of the metal, with which the undecomposed acid combines. By water the acid may be for the most part removed from this sulphate, so as to cause in it an excess of oxide so great as to render it competent for the production of tartar emetic, by digestion with the bitartrate of potash. In this case, the excess of oxide in the ulphate, and the excess of acid in the bitartrate, unite, converting the latter salt into the double tartrate of potash and antimony, or tartar emetic.

The reaction of diluted nitric acid with antimony is quite analogous to that already described in the case of bismuth. According to Berzelius, a subnitrate results, which may be decomposed by water as already stated, and converted into a hydrated sesquioxide. But Thenard nforms us that, if this metal be subjected to nitric acid, t is converted into hydrous antimonious acid (acide antimonieux blanc et hydraté). Possibly the difference may arise from the acid being in one case concentrated, in the other dilute.

Of the Compounds of Antimony with the Halogen Class.

Sesquichloride of antimony may be obtained, as Thenard alleges, by distilling the metal with the bichloride of mercury; also by the reaction of aqua regia with metallic antimony, and subsequent distillation of the resulting liquid, collecting the product in a fresh receiver when it becomes oleaginous in its consistency. He recommends as preferable, however, the action of chlorohydric acid on the sesquisulphide with heat, allowing the sulphydric acid gas to escape into the fire. The resulting liquid is to be decanted, and concentrated by heat in a retort until it acquires an oleaginous consistency.

The sesquichloride has been designated as the ***butter of antimony.*** It is white, semitransparent, very caustic, fusible below a boiling heat, and crystallizable in tetrahedrons by refrigeration. It is volatile at a heat below redness, and deliquescent, so as to be liquefied by exposure to air. It has already been mentioned that by subjecting this chloride to copious affusions of water, (eight times its weight, according to Thenard) an oxychloride results, formerly called the powder of Algaroth.

Bichloride of antimony, agreeably to the last mentioned author, exists only in combination with chlorohydric acid.

Perchloride of antimony is formed by the combustion of the metal in chlorine. It is a yellow liquid, sending forth thick fumes into the air, with a strong and disagreeable smell. It attracts moisture, and is, in consequence, at first converted into a white crystalline mass, but afterwards liquefied by a further accession of humidity. Yet by exposure to a large quantity of water with heat, it is decomposed, and deposites hydrous antimonic acid. This process is recommended as the best for obtaining this compound.

Of the Compounds of Antimony with Sulphur and Selenium.

It has been stated that antimony is procured principally from the native sesquisulphide, which is found in the shops under the name of *antimony*, the metal being distinguished as the *regulus*.

Sesquisulphide of antimony may be formed from its ingredients, by heating the metal in a state of division with sulphur. It is more fusible than metallic antimony, is crystalline in texture, has a metallic lustre, and a bluish-gray colour. It may act either as a sulphacid, or a sulphobase. With the sulphides of the alkalifiable metals it forms compounds which may be designated as hyposulphantimonites.

The sesquisulphide and sesquioxide of antimony enter into combination with each other in different proportions, forming compounds which must be called oxysulphides, consistently with the nomenclature adopted in the case of the analogous compounds of oxides with chlorides.

When the sesquisulphide of antimony is roasted, in other words exposed to heat with access of air, it becomes more or less oxidized, according to the duration of the exposure, the degree of heat, and the supply of air. If, after the roasting has continued for some time, the temperature be raised so as to fuse the mass, a vitreous compound will result, the composition of which will vary according to the ratio of the oxide to the sulphide, at the time of effecting the fusion. According to Thomson, when the ratio of the former to the latter is as five to one, the compound has the name of *crocus of antimony;* when the ratio is as three to one, it has been called *liver of antimony*. This name, however, is given by Berzelius to a compound of the sulphides of antimony and potassium or sodium.

If the sulphide of antimony, instead of being poured out as soon as it is melted, be kept for a great length of time in a state of fusion in an earthen crucible, it derives a portion of oxide of iron and silicic acid from the crucible, and thus forms a transparent mass of a yellow-hyacinth colour, commonly called the *glass of antimony*. This glass, according to Thenard, is a mixture of oxysulphide of antimony, with the silicates of antimony and iron.

By the reaction of the sesquisulphide of antimony with the alkalies, either caustic or carbonated, and either in the wet or dry way, a complicated reaction ensues, by which the antimony of the sulphide is more or less oxidized, the metal of the alkali more or less sulphurized; while the residual sulphide of antimony, acting as a sulphacid, combines more or less with the resulting sulphobase of the alkalifiable metal.

The extent to which the sesquisulphide, in the resulting sulphosalt, can e retained by the sulphobase in an aqueous solution, appears dependent pon temperature. Hence, whether the sulphosalt be produced in the dry vay and dissolved in hot water, or be generated by boiling the ingredients n this liquid, the sesquisulphide precipitates by refrigeration.

The precipitate thus obtained, under the name of *kermes mineral*, was o much in vogue in France, about a century ago, as to induce the governnent of that country to purchase from a surgeon of the name of La Ligeie, the art of preparing it.

Thenard alleges that it appears from the analysis of Henry, Jr., that he composition of kermes varies according to the process employed for ts production. When prepared by boiling the sesquisulphide in a soluion of ***carbonate*** of potash or soda, kermes may be considered as a hydrated xysulphide; but when procured by boiling the sesquisulphide in a soluion of ***caustic*** potash or soda, or by ***fusion*** with them or their carbonates, nd subsequent solution in hot water, it is a hydrated sesquisulphide, conaining very little if any oxide. As obtained by precipitation from tartar metic by sulphydric acid, it is a pure hydrated sesquisulphide. After the ermes has precipitated, a portion of the sesquisulphide still remains in nion with the sulphobase. Hence, on the addition of an acid, a further recipitation takes place, both of the sesquisulphide of antimony, and the ulphur of the sulphobase; and these, either by combination or mixture, onstitute the ***golden sulphur of antimony***, another well known pharmaeutical preparation.

According to the analysis of Henry, Jr., as quoted by Thenard, the omposition of kermes, when obtained in the wet way by carbonate of oda, is as follows:

Sesquisulphide of antimony, - - - -	62.5
Sesquioxide of antimony, - - - -	27.4
Water, - - - - - - -	10
Soda, - - - - - - -	a trace.

Upon the whole it is inferred that the sesquisulphide, in precipitating y refrigeration as abovementioned, combines with water in all cases; nd that when the process is conducted in the wet way by means of a arbonated alkaline solution, the precipitating hydrated sesquisulphide ombines with the sesquioxide, forming an oxysulphide. The presence f carbonic acid in union with the alkali is requisite, in order to enable the enstruum to form and dissolve while hot, a double carbonate of the alkali nd sesquioxide. The latter, being thus taken up by the aid of heat, ubsequently, in consequence of the refrigeration and its affinity for the ydrated sesquisulphide, precipitates in combination with this sulphide, as lready mentioned.

The officinal preparation, called ***precipitated sulphuret of antimony***, is btained by adding diluted sulphuric acid to a solution of the sesquisulhide of antimony in a hot solution of caustic potash. A precipitate reults which may be considered as a mixture of kermes mineral, and golden ulphur of antimony.

Bisulphide of antimony is obtained, according to Thomson, by dissolvng antimonious acid in chlorohydric acid, and subjecting the resulting iquid to sulphydric acid. I infer that four atoms of chlorohydric acid, cting on two atoms of antimony, in union with four atoms of oxygen, vill be productive of a bichloride, and that this will be converted into a isulphide by reaction with the sulphydric acid.

The bisulphide, being resolvable into the sesquisulphide and sulphur by heat, cannot be produced by the fusion of its constituents. It is of an orange-red colour, and acts as a sulphacid.

Persulphide of antimony is obtained by passing sulphydric acid through a diluted solution of the perchloride of this metal, to which tartaric acid has previously been added. Its colour resembles that of the bisulphide, though somewhat paler.

The selenide of antimony is obtained by heating this metal with selenium. Like the sulphide, it is capable of entering into combination with the oxide.

265. *Experimental Illustrations.*

Antimony and its sulphide, exhibited, and exposed to the blowpipe: also, the crystals and solution of tartar emetic. Kermes mineral, golden sulphur, and precipitated sulphuret of antimony, exhibited. Antimony, subjected to acids. Kermes mineral, precipitated from a solution of tartar emetic by sulphydric acid.

Of Tartrate of Potash and Antimony, usually called Tartar Emetic.

Before concluding the subject of antimony, I deem it expedient to subjoin the following extract respecting tartar emetic, the most useful of all the antimonial preparations. It is quoted from an article upon antimony, furnished by my friend Dr. Bache for the American Cyclopœdia of Practical Medicine, edited by Dr. Hays.

"Tartar emetic, called correctly the tartrate of antimony and potassa in the Dublin and United States Pharmacopœias, is a colourless, inodorous salt, possessing a nauseous styptic taste, and crystallizing usually in rhombic octohedrons. When prepared by means of the nitro-muriatic oxide,* its crystals have the appearance of tetrahedrons. As it occurs in the shops, it is in the form of a white powder, formed by the pulverization of the crystals. The crystals, when exposed to the air, effloresce slightly and become opake. Tartar emetic is insoluble in alcohol, but dissolves in fourteen times its weight of cold, and about twice its weight of boiling water. Its aqueous solution reddens litmus, and undergoes spontaneous decomposition by keeping. According to Berzelius, the protoxide† is precipitated from the solution of this salt by sulphuric, nitric, or muriatic acid, but not by the alkalies. Agreeably to Turner, a little pure potassa throws down the protoxide from a solution of tartar emetic, but takes it up again, if added in excess. According to the same authority, the alkaline carbonates throw down the protoxide much more completely. Turner also admits that the mineral acids throw down a precipitate; but instead of considering it, with Berzelius, the protoxide, he states it to consist of cream of tartar and a subsalt of antimony. It must be recollected, however, that on trying any of these precipitations, the solution of the antimonial salt must be strong, and the several precipitants not added too freely, otherwise they will produce no effect.

---

* Oxychloride. † Sesquioxide.

"Tartar emetic is precipitated in a very characteristic manner by sulphuretted hydrogen, which throws down an orange-red precipitate, consisting of hydrated sesquisulphuret of antimony.

"When tartar emetic is pure, it should exhibit its appropriate crystalline appearance, and be entirely soluble in distilled water. Its solution should not be precipitated by muriate of baryta,* oxalate of ammonia, acidulous nitrate of silver, or acidulous acetate of lead. A precipitate by the first reagent indicates sulphuric acid; by the second, lime; by the third, muriatic acid; and by the fourth, cream of tartar. The most usual impurities which it contains, are uncombined cream of tartar, tartrate of lime, silica and iron, and sulphate of lime. Cream of tartar is present, usually either from its having been used in excess in preparing the salt, or from fraudulent admixture. Tartrate of lime is derived from the cream of tartar, which always contains this impurity, as found in the shops. It is apt to form on the surface of the crystals of tartar emetic in crystalline tufts, which are easily brushed off. Silica and iron are liable to be present when glass of antimony has been employed in preparing the antimonial salt, and the evaporation has been carried too far. Sulphate of lime is sometimes an impurity, when tartar emetic has been prepared by means of the subsulphate. According to Serullas, tartar emetic as ordinarily prepared, and all the other antimonial preparations, usually contain a minute portion of arsenic, derived from the native sulphuret of antimony, which almost always contains this dangerous metal. Its presence in tartar emetic may be detected by exposing the salt to the action of the blowpipe, when the peculiar odour of the arsenic will be perceived. This dangerous impurity, however, is not present in well-crystallized tartar emetic, a fact which should form a strong additional motive with the apothecary, always to purchase this antimonial in crystals.

"Besides being decomposed by the mineral acids, the alkalies whether pure or carbonated, sulphuretted hydrogen, and hydrosulphates,† the same effect is produced by many other substances. Thus, it is decomposed by some of the metals and their oxides, by lime-water and muriate of lime,‡ and by the acetate and subacetate of lead. This antimonial salt is also affected by common water when holding carbonate of lime in solution, but not when containing muriates,§ sulphate of lime, or extractive matter. Hence it is necessary to dissolve it in distilled water, when the pure effects of the medicine are designed to be produced. Other substances which decompose tartar emetic, are the decoction of tamarinds, lemonade, whey, and generally all bitter and astringent vegetables, such as Peruvian bark, rhubarb, galls, catechu, &c. Of these different substances, some precipitate the antimonial oxide, and others produce new salts with it, either soluble or nearly insoluble; but it by no means follows that they render the tartar emetic inert. On the contrary, the ordinary effects of the medicine are produced, though by the agency of the new combinations formed. Some doubt, however, may be entertained whether this remark will apply to the effects of the bitter and astringent vegetable medicines, which owe their power of decomposing tartar emetic to the presence of tannin, which forms an insoluble compound with the oxide of antimony. Nevertheless, Laennec has remarked that, though cinchona and infusions of other vegetables precipitate tartar emetic, still the new compounds formed have the same properties as those of the tartar emetic itself. It is difficult to believe this statement without some qualification; as the evidence is very strong in proof of the influence of bark and other astringent vegetables, in mitigating the effects of an over-dose of tartar emetic. The truth probably is, that the tannate of antimony, produced by these vegetables, is not inert, though by no means so active as the undecomposed salt; and that it is capable of producing similar effects with tartar emetic, provided it be given in a sufficient dose.

---

* Chloride of barium.

† Sulphydrates.

‡ Chloride of calcium.

§ Chlorides.

"Tartar emetic enters into but three officinal preparations, contained in the British and United States Pharmacopœias. These are antimonial wine, tartar emetic ointment, and Coxe's hive syrup (mel scillæ compositum. Ph. U. S.)."

Tartar emetic may be considered as consisting of

Two equivalents of tartaric acid,	66 × 2 = 132
One of sesquioxide of antimony,	152
One of potash,	48
Two of water,	9 × 2 = 18
	350

SECTION XIII.

OF METALS PROPER OF MINOR IMPORTANCE.

OF PALLADIUM.

Besides iron, copper, and lead, four metals, palladium, rhodium, iridium, and osmium, are found in union with, or accompanying, the native grains of platinum, as imported from South America. Accordingly, if a portion of that assemblage of metallic particles, of which the native grains of platinum above mentioned form the principal part, be digested in aqua regia, the platinum, together with the palladium, rhodium, copper, and lead, will be dissolved; while a black powder will be left, consisting of osmium and iridium in combination with each other.

The platinum may be precipitated from this solution, as has been already stated, by the addition of the chloride of ammonium. Next all the noble metals present are precipitated by a bright plate of zinc. They are then digested in chlorohydric acid, and subsequently redissolved in aqua regia. Any excess of acid in the resulting solution should be neutralized by carbonate of soda. Afterwards the palladium may be precipitated by the addition of the bicyanide of mercury. From the cyanide of palladium, thus precipitated, the palladium may be liberated by a red heat.

Mr. Cloud, of the United States mint, found this metal in a native alloy of gold which was brought from Brazil.

Palladium resembles platinum in colour and lustre, but is more fusible and rather harder. Its specific gravity, also, is much less, being about 11.5. It is malleable and ductile, and insusceptible of oxidizement by heat and air.

OF RHODIUM.

After the palladium has been precipitated, the solution contains the chlorls of rhodium, mercury, and several other metals, united with the chlo(or chlorobase) of sodium, resulting from the carbonate of soda, emyed as above mentioned to neutralize the excess of acid. There is wise present a portion of the undecomposed bicyanide of mercury. der these circumstances, chlorohydric acid must be added, in order to vert this bicyanide into a bichloride, and the solution afterwards must vaporated to dryness. The resulting mass should then be washed with hol, which dissolves all the chlorosalts of sodium present, except the rhodiate. Rhodium is obtained from this by heating it in a curt of hydrogen which removes the chlorine combined with the metal, the ride of sodium being removed by water.

Rhodium, according to Berzelius, cannot be fused, except by subjecting when in the state of a sulphide or arseniuret, to an intense heat. After on, it resembles platinum in appearance. Its salts are generally either or yellow. It is named from its chloride, which is rose-red.

OF IRIDIUM.

When the black powder, consisting of the osmiuret of iridium, which ains as above stated, after we have subjected the crude grains of platia to aqua regia, is heated with soda, an osmiate of soda is formed, ch may be removed by dissolving it in water. The remaining mass be treated with aqua regia, in which the iridium, converted into a ride, dissolves. By repeating this process, the whole is finally coned into solutions of chloride of iridium, and of osmiate of soda.

rom the former, crystals of the chloride of iridium may be obtained evaporation, which, on exposure to a strong heat, yield metallic irim.

ridium resembles platinum in appearance, and is probably, according Thomson, the heaviest of the metals. When heated in contact with nearly to redness it is oxidized, but on the application of a higher temature it is again restored to the metallic state. Thenard, however, es that iridium which has been subjected to a strong heat, is absolutely sceptible of oxidizement by the air at any temperature.

ridium is said to be the most refractory of the metals, having never n fused until it was placed between the poles of Children's large galic battery. It was then converted into a globule, possessing metallic teness and lustre.

OF OSMIUM.

Osmic acid may be obtained by distilling the solution of osmiate of soda, cured as above described, with nitric acid at a gentle heat. The osmic d passes over, and may afterwards be reduced by the addition of chloydric acid and mercury. It is, however, alloyed with mercury, and gled with the chloride of this metal. These may be sublimed by a tle heat, leaving pure metallic osmium.

Obtained in this way, osmium is of a grayish-black colour; but if a tion of the volatilized oxide be made to pass with a current of hydrogen ough a glass tube, the osmium is deposited in the form of a ring of meic brilliancy, and of a white colour. It is so difficult to fuse in close sels, and so liable to be volatilized when heated in the air, that it has y been obtained in powder, or in minute friable masses. Its volatility in the air arises from its great susceptibility of oxidizement, and the volatility of its oxide, the fumes of which are pungent.

OF NICKEL.

A mineral had been known to the German miners by the name of kupfer nickel, or false copper. About the middle of the last century, Cronstedt alleged the existence, in this mineral, of a peculiar metal. Nevertheless, the metal, thus indicated, was considered by many chemists as an alloy of copper with iron. About 1775, Bergmann confirmed, by an analysis, the allegation of Cronstedt.

Kupfer nickel is principally an arseniuret of nickel, but contains, also, sulphur, iron, cobalt, and copper. Nickel is extricated from it by a tedious and intricate process.

Nickel is of a white colour, difficult of fusion, malleable and not easily oxidized by the air. It is so susceptible of the magnetic influence that a permanent magnet may be made of it. If sufficiently abundant, nickel would be very valuable in the arts. It combines with oxygen, chlorine, iodine, cyanogen, sulphur, and the metals. Its oxides are soluble in the acids, and in their habitudes are much like those of copper. The solubility of its protoxide in caustic ammonia, is an important means of separating nickel from its alloys.

OF CADMIUM.

This metal has been derived only from the ores of zinc. During the reduction of calamine, a substance sublimes which yields from 12 to 20 per cent. of cadmium.

A solution of the ore in sulphuric acid, being impregnated with sulphydric acid, the cadmium precipitates in the state of sulphide, mixed with a little sulphide of zinc, and sometimes with sulphide of copper. When these sulphides are exposed to chlorohydric acid, the sulphur unites with the hydrogen of the acid and escapes, and they are converted into chlorides. Carbonate of ammonia being added to the resulting solution of cadmium and zinc, a carbonate of cadmium is alone precipitated. From this, the metal may be obtained by means of heat and charcoal.

Cadmium is almost as white as tin, is without odour or taste, very brilliant, and susceptible of a fine polish. It is crystallizable, malleable, and ductile, and so soft as to yield easily to a file or knife. Its specific gravity is 8.6 nearly. It is too scarce to be usefully applied. It fuses and volatilizes at a very low temperature.

OF CHROMIUM.

This metal is found in nature only in the state of an acid and of an oxide, generally united with lead or iron, though in some instances pure. It was in the native chromate of lead, found usually in crystals which rival the ruby in colour, that this metal was discovered by Vauquelin. A compound of the sesquioxides of chromium and iron, called incorrectly chromate of iron, is found plentifully in this country. The sesquioxide of chromium, when intensely heated with charcoal, is reduced, but not without great difficulty.

The presence of chromium in a mineral may be detected by the fusion of a minute portion before the blowpipe with borax, or, preferably, with the ammoniacal phosphate of soda. In this way, a globule of a beautiful d green results, which preserves its colour either in the oxidizing.

r reducing flame. By these characteristics it may be distinguished from opper or uranium; since uranium communicates a green hue only in the educing flame, copper only in the oxidizing flame.

Chromium is a hard, brittle metal, of a grayish-white colour, and very ifficult to fuse. Its specific gravity is 5.9. Its equivalent is 28. It forms rith oxygen a sesquioxide and an acid. The compound, heretofore con- idered as a deutoxide, proves to be a mixture of sesquioxide and chromic cid.

The sesquioxide of chromium is easily obtained by exposing the chro- nate of mercury to heat, by which the mercurial oxide and a portion of he oxygen of the acid are expelled, while the sesquioxide remains in the orm of a grass-green powder.

It may also be obtained in the state of hydrate, by mixing solutions of he bichromate of potash, and persulphide of potassium. This sesquioxide s of a beautiful green colour, which it communicates to some of its com- ounds, being in fact the colouring matter of the emerald. It appears to ct both as an acid and a base.

In common with zirconia and oxide of titanium, the sesquioxide of chro- iium, when obtained from the hydrate by expelling the water by a gentle eat, becomes incandescent at a certain elevation of temperature, in a way hich is altogether unaccountable. At the same time it loses its property solubility in acids which it before possessed.

Chromic acid may be procured by the following process:—Let four parts the chromate of lead be mixed with three parts of fluoride of calcium, th finely pulverized. Then let five parts of sulphuric acid, deprived of ater as far as possible by boiling, be added, and let the whole be distilled a leaden or platinum alembic at a gentle heat. A red gas will be de- loped, producing in the air, yellow fumes. This red gas is a fluoride of romium, which, on being passed into water, is converted into fluohydric d chromic acids. The former may be expelled by evaporation, the romic acid remaining in a state of purity.

If instead of causing the gaseous fluoride of chromium to enter water, it conducted by means of a tube into a receptacle of platinum, closed with oistened paper, and having a small quantity of water at the bottom, the s will be decomposed by the aqueous vapour, mingled with the air of the ssel, and will deposite first about the mouth of the tube, and afterwards roughout the vessel, a flocky vegetation, consisting of ruby-red crystals f chromic acid.

Chromic acid is solid, soluble in water, and capable of reddening litmus. is decomposed by heat, and by most substances which possess an affi- ity for oxygen. It possesses an acid and astringent taste, and a ruby-red olour, which it communicates to some of its compounds, as already no- ced in the case of native chromate of lead. It forms striking and beau- ful precipitates with various metals. That which it produces with lead, of a splendid orange-yellow, and is much used as a pigment. The co- our of the streak left by the red crystals above described, when rubbed pon a hard surface, is likewise orange-yellow; and the same change en- ues from pulverization. The bichromate of potash is poisonous, and no oubt the acid and its compounds are generally poisons.

Chromic acid creates a stain upon the skin which cannot be removed vater, unless it contain an alkali. Where there is any abrasion of uticle, the presence of this acid will induce a painful ulcer. ores to which dyers are exposed who employ bichromate o dye-stuff. These sores have been alleged to arise even from exposure to the vapours or fumes of this acid. When received into the stomach, chromic acid is a virulent poison. Dr. Ducatel informs us of the case of a labourer who died in five hours, after drawing into his mouth from a syphon, a solution of bichromate of potash; although he was under the impression that, by spitting, he had avoided taking it into his stomach.

Dr. Ducatel suggests an alkaline solution as the best antidote; as he ascribes the poisonous property of the bichromate mainly to the excess of acid. An instance of a criminal prosecution for poisoning by the salt in question is mentioned, which failed from that ignorance of its deleterious properties which Dr. Ducatel's communication must tend to correct.*

OF COBALT.

This metal is found in nature, principally in union with arsenic. By the exposure of the mineral, thus containing it, to heat, with access of air, the arsenic is oxidized and expelled, and the cobalt is reduced to the state of an impure oxide, called *zaffre.* By fusion with the alkali and sand, zaffre yields a beautiful blue glass, which, when pulverized, forms the blue vitreous powder called *smalt.*

Cobalt may be obtained from its oxide, by intense ignition with charcoal, or by subjecting it, while ignited in a porcelain tube, to a current of hydrogen.

Cobalt is brittle, of a grayish-white colour, and feeble lustre. Its specific gravity is 8.5 nearly. It requires a high temperature for its fusion.

OF COLUMBIUM.

A metal discovered by Hatchett, in 1801, in a mineral obtained from America, received the name of *columbium.* It was afterwards detected by Ekeberg in two Swedish minerals, called tantalite, and yttrotantalite; and being supposed to be a new metal, was called *tantalum.* Wollaston afterwards demonstrated the identity of tantalum with columbium.

This metal is found in the state of an acid, combined either with manganese and a little iron, or with yttria. Both combinations are very rare. It may be reduced by heating the fluocolumbate of potassium, or fluoride of columbium and potassium, with potassium.

Columbium is a brittle metal, of an iron-gray colour, having the metallic lustre. It is infusible by the most intense heat of the forge fire.

OF MANGANESE.

Manganese exists in nature principally in the state of a black bioxide; rarely in that of phosphate, sometimes in the state of sulphide. The utility of this oxide, as a source of oxygen gas, as an ingredient in glass, and as one of the agents for evolving chlorine, has been noticed. The metal is obtained by heating the oxide intensely with charcoal or potassium. It is gray, brittle, hard, and scarcely fusible by the highest heat of the forge, or air furnace. In the metallic state, it has not been applied to any useful purpose.

Manganese is remarkable for the number of compounds which it forms with oxygen. Besides a protoxide, sesquioxide, and bioxide, it forms two acids, the manganic, and oxymanganic or permanganic acids. The salts of the latter detonate with combustibles.

---

* See Journal of the Philadelphia College of Pharmacy, for January, 1834, page 272, vol. 5.

When the black oxide (bioxide) is fused with nitrate of potash, a compound results, of which the aqueous solution becomes blue, violet, and red, and finally colourless. Hence this compound has been called *chameleon mineral.*

These colours appear to be produced by the conversion of the manganate of potash, into an oxymanganate.

OF MOLYBDENUM.

This metal is only found in the state of sulphide, resembling plumbago, or united with oxygen and lead in the state of molybdate of lead. From the sulphide it is obtained by ebullition with nitric acid, which acidifies both the sulphur and metal. The sulphuric acid being expelled by heat, the molybdic acid is decomposed by intense ignition with charcoal.

As from the difficulty of fusing it, molybdenum has been only obtained in small grains, its properties are but little known. It is alleged to have a high degree of metallic lustre, and a white colour.

OF TITANIUM.

Titanium, like many other metals, is only interesting as an item in the knowledge which human skill and assiduity have accumulated, with respect to the materials of the globe which we inhabit. It is obtained by separating the oxide from the substances with which it is naturally mixed, and heating it intensely with charcoal.

Titanium was first ascertained to exist in the state of oxide, by Mr. Gregor, in a mineral called *menachanite.* It was subsequently detected in the metallic state by Dr. Wollaston, in minute cubic crystals, in the slag found at the bottom of a smelting furnace.

These crystals were conductors of electricity, of the specific gravity of 5.3, and hard enough to scratch rock crystal. In colour and lustre, they were like burnished copper. They resisted the action of nitric acid and aqua regia, but were oxidized by being heated with nitre.

OF TUNGSTEN.

In 1781, Scheele, having analysed a stone known by the name of tungsten, or heavy stone, concluded that it consisted of an acid united with lime. Bergmann suspected the radical of this acid to be metallic. Messrs. D'Elhuyart verified his conjecture, by heating tungstic acid intensely with charcoal.

Tungsten is grayish-white, brilliant, and extremely difficult to fuse. Its specific gravity is 17.6.

OF URANIUM.

Uranium is a rare production in nature, and has scarcely been found in sufficient quantities for an adequate observation of its properties. It is stated to have the metallic lustre, a reddish-brown colour, to be crystalline in its structure, and scarcely susceptible of fusion by the heat of a forge fire.

OF CERIUM.

Cerium, according to Vauquelin, who was unable to obtain it in masses larger than the head of a common pin, is a white brittle metal. From some experiments made by Children and Thomson, it appears to be susceptible of volatilization.

OF VANADIUM.

Vanadium was discovered, in 1801, by Del Rio, in a lead ore from Zimapan, in Mexico; but Collet Descotils, to whom the mineral was sent, having made some new experiments upon it, pronounced it to be an ore of chromium. Del Rio himself having acquiesced in this opinion, it was generally adopted until 1830, when Sefstrom discovered this metal again in a variety of Swedish iron, and in the scoria of the forge at which the iron had been wrought.

Vanadium resembles molybdenum in appearance; and in its properties lies between that metal and chromium.

266. *Experimental Illustrations.*

Exhibition of various specimens of the metals mentioned in the preceding pages. Magnetic influence of nickel, demonstrated. Solutions of silver, mercury, and lead, precipitated by chromate of potash. Sesquioxide of chromium, evolved by heating the chromate of mercury. Exhibition of the fluoride of chromium. Effects of cobalt, also of manganese, upon vitrified borax.

SALTS.

It has, I believe, been shown in my letter upon the Berzelian nomenclature, that it is not possible to give a satisfactory definition of a salt, whether we refer to properties or composition. The best definition which I can devise, in this case, is that a salt is a compound, resulting from the union of at least two acid, acrid, or corrosive ingredients; forming, agreeably to the language of the older chemists, a *tertium quid*, or in plain English, a *third something*, differing materially from its constituents. It should, as I conceive, be crystallizable, and soluble either in water or alcohol. I do not think that a satisfactory line of demarcation can be drawn between salts, acids, and bases.

Some compounds which lean so much towards *salidity** in their characteristics, as to have been classed with salts, have latterly been found to play the part of acids or bases, as instanced by the binary halogen salts. Now I would consider them as salts when acting as such, and as acids or bases when acting as acids or bases. Berzelius himself has suggested this kind of contingent definition in the instance of water; which he represents as acting as a base with some acids, and as an acid with some bases. Thus it seems possible for the same body to act either as an acid, a salt, or a base, accordingly as it may be associated.

As respects composition, I conceive that there are at least three groups of salts.

1st. Binary saline compounds of a halogen element and a metal.

2d. Saline compounds of acids and bases, tertium quids agreeably to the definition of acidity and basidity, page 252.

3d. Saline compounds of acids with organic bases.

As far as consistent with the due allotment of time, I have given an account of the 1st class in treating of the metals. But the class thus constituted are capable of combining with each other, and with the electro-negative or acid compounds, formed by the union of their halogen ingredients with non-metallic radicals. In this way compounds are produced, which Berzelius designates as double haloid salts. I, however, consider them as much entitled to be treated as saline compounds of acids and bases, as the double sulphides, selenides, or tellurides, which are so treated by that distinguished chemist. Thenard coincides with me in opinion on this subject, as I have already stated, page 343.

I shall designate the salts comprised in the 1st and 2d groups abovementioned by their basacigen ingredients. See page 251. Hence the nine following classes; *oxysalts*, *sulphosalts*, *selenisalts*, *tellurisalts*, *chlorosalts*, *bromosalts*, *iodosalts*, and *cyanosalts*. Of these the first four are formed by the *amphigen bodies*, and the rest by the *halogen bodies* of Berzelius.

---

* I am unable to refer to any authority for the use of this word, but conceive myself justified in employing it, as by its analogy with *acidity*, it must be understood by the reader.

SECTION I.

OF OXYSALTS.

In describing the oxysalts, I shall be constrained to confine my remarks to some of the more important characteristics of each of the sets of salts formed by the different inorganic oxacids with the more energetic bases. Some of those formed by acids of minor importance will be omitted altogether.

The student is referred, for an account of the nomenclature of oxysalts, to page 250.

OF CHLORATES.

When into a solution of potash (oxide of potassium), chlorine is introduced, one portion of it combines with the potassium, separating from each atom, the atom of oxygen by which it was oxidized. The oxygen thus liberated from several atoms of the metal, coming into contact with another portion of chlorine, forms with it chlorous acid. Each atom of the acid, thus formed, unites with an atom of potash, producing a chlorite. By continuing the operation until all the potash which remains free is decomposed, that which has meanwhile united with the acid is attacked by the chlorine, and the oxygen, liberated in consequence from each atom of the chlorite, converts another portion of this salt into a chlorate. This salt, being inferior in solubility to the chloride, precipitates in crystals, which, being subjected to boiling water, are purified by the recrystallization which cooling induces.

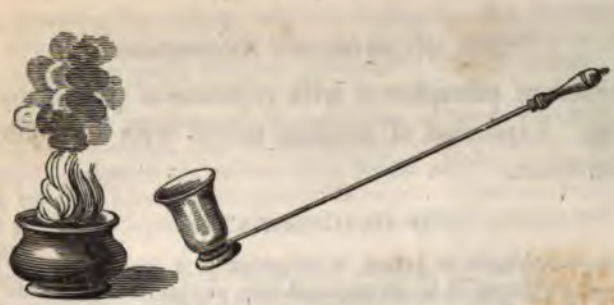
Properties.—The chlorates resemble the nitrates in deflagrating with combustibles; but the residuum which they leave is always a chloride; and the deflagration is more powerful and more easily effected. If chlorate of potash be triturated in contact with sulphur or phosphorus, an explosion ensues. Salts of this class give up their oxygen, and are converted into chlorides, simply by being heated. They are almost all soluble in water. The chlorate of the protoxide of mercury is said to be but sparingly soluble.

The chlorates are not of much use in the arts; but the facts ascertained, and the phenomena exhibited by means of them, are highly interesting. The properties of the chlorates are most conveniently illustrated by the chlorate of potash.

Priming for percussion locks has been made by mingling the chlorate of potash with combustibles. In like manner, matches to be ignited by sulphuric acid have been contrived. For the former purpose fulminate of mercury is preferable. See further on, page 421. Alcohol, or any of the essential oils, oil of turpentine for instance, may be ignited by means of chlorate of potash and sulphuric acid.

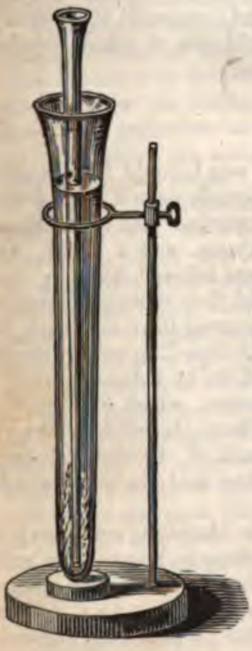
267. *Inflammation of certain Liquids by means of Chlorate of Potash and Sulphuric Acid.*

About as much chlorate of potash as may be piled upon a half cent, being deposited in a heap amid the inflammable liquid, the affusion of concentrated sulphuric acid upon the heap, causes the liquid to be inflamed.



As portions of the liquid are sometimes projected into the air in a state of inflammation, it is expedient, for the security of the operator, to have the glass, used to convey the acid, fastened to the end of a rod, as represented in the cut.

Agreeably to the statements made at pages 168, 169, when sulphuric acid is poured upon chlorate of potash, this salt is at first partially resolved into free chlorous acid, and oxychlorate of potash. The oxygen and chlorine of the liberated acid produce, by contact with combustible matter, an explosive reaction. For the rationale of the explosive power, as far as I am competent to throw light upon a subject so abstruse, I refer to what is said on *Theories of Combustion*, at page 243, and again to pages 115, 116.



268. *Combustion of Phosphorus under Water, by means of Chlorate of Potash and Sulphuric Acid.*

Let there be two tubes, one within the other, as here represented; the larger one, closed at the lower end, and containing water; the other open at both ends, the upper orifice funnel-shaped, and the bore about one-eighth of an inch in diameter. Allow some very small pieces of phosphorus, and a few crystals of chlorate of potash, to fall down to the bottom of the large tube. Then, into the smaller tube, pour some sulphuric acid; so that, without being much diluted, it may descend upon the chlorate and phosphorus. A vivid ignition ensues, in despite of the water which surrounds the agents by which the fire is produced.

The sulphuric acid, uniting with the potash of the chlorate, liberates chlorine and oxygen, which, coming into contact with the phosphorus, cause its combustion, although surrounded by water.

269. *Experimental Illustrations.*

Ignition of phosphorus with chlorate of potash by percussion. Explosion of sulphur mixed with the chlorate, by trituration.

OF OXYCHLORATES.

When the chlorate of potash is subjected to a temperature of nearly 750°, one portion of it is decomposed into oxygen, and chloride of potassium. Part of the oxygen, while nascent, combines with an undecomposed portion of the salt, forming with it an oxychlorate. As the oxychlorate is soluble to a considerable extent in boiling water, and nearly insoluble in cold, it follows that, if the resulting mass be dissolved in water of the temperature of 212°, and the solution allowed to grow cold, the oxychlorate of potash precipitates in crystals, while the chloride of potassium remains dissolved. The oxychlorates of the other bases are obtained either by the direct union of the acid with the base, or by double decomposition. For the mode of procuring oxychloric acid, see page 170.

The oxychlorates, in general properties, resemble the chlorates. They appear, however, to be more permanent; since the oxychlorate of potash is not decomposed by any of the acids at ordinary temperatures, and does not react as violently with sulphur as the chlorate of potash.

Nearly all of the oxychlorates would appear to be deliquescent, and soluble in alcohol, excepting those of potash, lead, protoxide of mercury, and ammonia. (At the temperature of 59°, oxychlorate of potash requires for its solution sixty-five times its weight of water.)

OF CHLORITES.

It had long been known that, when chlorine was brought into contact with the fixed alkalies or alkaline earths, compounds were formed which possessed powerful bleaching and disinfecting properties. As it was found that such compounds consisted of chlorine, oxygen, and a metal, and yielded chlorine when acted on by an acid; it was inferred that they consisted of chlorine united to a metallic oxide, and their striking properties were ascribed to that element, as it appeared to possess them in a high degree. Their increased activity, either in smell or bleaching power, resulting from the addition of an acid, was accounted for by supposing that it liberated the chlorine. A number of facts, however, which it would occupy too much space to state here, have since been observed, tending to prove that the bleaching salts are not compounds of chlorine with oxybases, but salts formed by these bases with chlorous acid; in other words, *chlorites.*

Although this opinion was sanctioned by some chemists, and many of the phenomena which had been observed were otherwise inexplicable, still, on account of the impossibility of procuring a chlorite without the admixture of a chloride, it was found impracticable to submit it to a definite proof. Latterly, however, Balard has succeeded in obtaining chlorous acid, by the action of chlorine on the bioxide of mercury, suspended, in a state of minute division, in water. Under these circumstances, one portion of the chlorine forms a bichloride of mercury with one portion of the metal, liberating the oxygen; while the bichloride, thus generated, combines with the undecomposed part of the bioxide, producing an oxychloride. This being nearly insoluble, precipitates; and the liberated oxygen, meanwhile uniting with another portion of the chlorine, produces chlorous acid, which may be separated, by distillation, in union with water. The solution, thus obtained, may be concentrated by evaporation, and the acid afterwards evolved in the gaseous form, by the addition of nitrate of lime, which liberates it by combining with the water. Chlorous acid, whether in the gaseous or liquid state, forms chlorites with the alkalies and alkaline earths.

According to Balard, chlorous acid, obtained by his process as above given, differs somewhat in properties from the compound of chlorine and oxygen, described in the preceding part of this Compendium as chlorous acid. It was there mentioned, that, while some chemists considered it as containing four atoms of oxygen to one of chlorine, agreeably to the preferable opinion of Berzelius, it was to be viewed as containing only three atoms of oxygen to one of the other ingredient. Yet Balard states that the new acid which he has obtained, contains but two atoms of oxygen united with one of chlorine. But the compound heretofore known as chlorous acid, when brought into contact with bases, produces a chlorite, a chloride, and a chlorate. It would, therefore, appear probable, that it is a compound of *chlorous* and *chloric acid*, possessing properties similar, in many respects, to those which Berzelius attributes to nitroso-nitric acid, and that the variation which has been observed in its composition, may be accounted for by supposing the occasional presence of a portion of chlorous, uncombined with chloric acid.

The impure chlorite of lime, called bleaching salt, is obtained by exposing hydrate of lime to chlorine. Analogous chlorites of potash and soda are found in the mother waters of the chlorates of those alkalies, and may likewise be obtained, by double decomposition, from the chlorite of lime, and carbonate of potash or soda. When obtained by these methods, chlorites are mingled with the chlorides of the metals peculiar to their respective bases.

Properties.—The chlorites are extremely susceptible of decomposition. This, however, takes place in a manner which varies with the circumstances in which they are placed. Bleaching or disinfection is effected by a chlorite when quite pure, by imparting oxygen; being resolved into this element and a chloride. Chlorine produces similar effects, by causing water to impart oxygen. No doubt the result is the consequence of complex affinity, the hydrogen being attracted by the chlorine, the oxygen by some oxidizable substance.

When carbonic acid has access to a chlorite, it combines with the base of the salt, displacing the acid; and if a chloride be present, its radical is oxidized by the oxygen of the acid thus displaced, while its chlorine is liberated, as well as that of the chlorous acid. Of course an evolution of chlorine must ensue from the employment in like case of any acid, which, in its affinities, is not less energetic than carbonic acid. If, however, a pure chlorite, formed by the action of chlorous acid on a base, be subjected to the action of a more powerful acid, the chlorous acid may be liberated without being decomposed.

When an aqueous solution of a chlorite is boiled, no acid being present, one portion of the chlorite is converted into a chloride; while the oxygen which is liberated from it during this transformation, converts another portion into a chlorate.

According to Thomson, when chloride of ammonium is introduced into a retort containing the chlorite of lime of commerce, made into a paste with water, gaseous nitrogen is evolved with a reaction so violent, that, in order to delay the extrication until his arrangements for collecting the product were completed, he found it expedient to wrap the chloride in blotting paper.

270. *Experimental Illustrations.*

Production of chlorite of lime. Its effects upon colouring matter. Evolution of nitrogen from chloride of ammonium, by chlorite of lime.

OF NITRATES.

This class of salts is distinguished by deflagrating with charcoal and other combustibles. When the combustible is susceptible of acidification, the resulting acid unites always with the base. Thus in the case of charcoal, a carbonate is left; in the case of sulphur, a sulphate; in the case of arsenic, an arseniate. They differ from the oxysalts containing an acid with a halogen radical (the chlorates for instance), in leaving an oxide after deflagration, instead of a haloid salt. Thus the nitrate of potash leaves the oxide of potassium; while the chlorate leaves a chloride of potassium.

If subjected to concentrated sulphuric acid, the nitrates, when dry, emit fumes of nitric acid. When added to liquid chlorohydric acid, by dehydrogenating the chlorine, they enable it to act on gold leaf, as it does when presented to this metal in aqua regia.

The neutral nitrates are all soluble, and many of them deliquescent.

271. *Experimental Illustrations.*

Deflagration of a nitrate upon ignited charcoal, and of charcoal and other substances upon a fused nitrate. A nitrate added to liquid chlorohydric acid containing gold leaf, causes the solution of the metal. Decomposition of a nitrate by heat.

OF NITRITES AND HYPONITRITES.

It would appear that the compound, which, consistently with the practice of the British and French chemists, has been designated as nitrous acid, is decomposed when presented to bases, forming a nitrate and hyponitrite.

It is probable, therefore, that there are no salts which properly deserve the name of nitrites, in the sense in which this appellation has been used by the chemists above mentioned. It has already been stated that Berzelius does not admit the existence of any acid intermediate, as respects the quantity of oxygen contained, between nitric and hyponitrous acid, and, therefore, calls the acid to which the last mentioned name has been applied, nitrous acid, and of course designates its compounds as nitrites. The hyponitrites of the English and French chemists, or nitrites of Berzelius, resemble the nitrates in most of their properties; but may be recognised by the red vapours which they evolve on the addition of any of the stronger acids.

OF SULPHATES.

Their solutions all yield precipitates with solutions of baryta. Heated in contact with charcoal or hydrogen, they are converted into sulphurets, which, if moistened, smell like rotten eggs. They are almost all insoluble in alcohol. The sulphates of baryta, tin, antimony, bismuth, and lead, are *quite* insoluble in water. Those of strontia, lime, yttria, mercury, silver, and the sesquioxide of cerium, are *nearly* insoluble; while all other sulphates are soluble.

272. *Experimental Illustrations.*

Precipitation of sulphates by solutions of baryta. Conversion of a sulphate into a sulphuret before the blowpipe, demonstrated by the subsequent effect upon a metallic solution.

OF HYPOSULPHATES, SULPHITES, AND HYPOSULPHITES.

The hyposulphate of baryta, is obtained by adding sulphide of barium to a solution of hyposulphate of manganese, procured as described, page 181. The hyposulphates of lime and strontia are procured in the same manner, and the hyposulphates of the other bases, either by double decomposition, or by adding the acid directly to the base.

The neutral *hyposulphates* are probably all soluble. This property, together with their conversion into sulphates by heat, and the odour of sulphurous acid which they emit on the addition of concentrated sulphuric acid, is sufficient to enable us to recognise them.

The insoluble *sulphites* are obtained by double decomposition; those which are soluble, by the direct action of the acid on the base.

The sulphites are generally insoluble, and may be recognised by the odour of sulphurous acid which they emit on the addition of diluted sulphuric acid; while they do not, like the hyposulphites, simultaneously deposite sulphur: also by their not yielding, like the hyposulphates, a neutral sulphate by heat.

The *hyposulphites* are procured by treating metallic zinc, iron, or manganese, with liquid sulphurous acid. Each atom of this acid abandons one atom of oxygen to the metal, being consequently converted into hyposulphurous acid, which, with the resulting oxide, forms a hyposulphite.

The hyposulphites may likewise be formed by boiling sulphites with flowers of sulphur, by which each atom of acid in any sulphite takes up an additional atom of sulphur, converting the sulphite into a hyposulphite.

The hyposulphites may all be decomposed by heat, and, when acted on by sulphuric acid, deposite sulphur and liberate sulphurous acid.

OF SELENIATES.

The seleniates greatly resemble the sulphates in properties. They are in fact isomorphous with them, and crystallize with the same quantity of water of crystallization. The seleniates are, however, more susceptible of decomposition than the sulphates, and when thrown on burning coals deflagrate.

OF PHOSPHATES.

The phosphates all give precipitates with solutions of baryta, lime, lead, and silver.

The phosphates are not decomposable by heat alone. Those of the metals proper may be converted, by heat and charcoal, into phosphurets of the metals peculiar to their respective bases. In the case of the phosphates of the earths and alkalies, a portion of the phosphoric acid is deoxidized by the carbon, evolving phosphorus; while the remainder forms with the base a subphosphate.

By heat the phosphates are converted into paraphosphates, identical in composition, though different in properties. See page 268.

According to Thenard, phosphoric acid combines with bases in five different proportions, forming ***biphosphates***, ***sesquiphosphates***, ***neutral phosphates***, ***sesquibasic phosphates***, and ***bibasic phosphates***, in which the equivalents of acid to those of the base are respectively as 2 to 1, 1½ to 1, 1 to 1, 1 to 1½, and 1 to 2.

OF PHOSPHITES.

The phosphites are obtained either by presenting the acid directly to the base, or by double decomposition. When thrown on burning coals they produce a yellow flame, the colour of which increases in intensity with the quantity of acid contained in the salt.

OF CARBONATES.

This class of salts is distinguished by being susceptible of decomposition, with effervescence, by any of the acids, excepting a few that are remarkably feeble, as, for instance, the cyanhydric and meconic acids.

All the alkaline carbonates are decomposable by heat, excepting those of potassa, soda, baryta, strontia, and probably lithia.

Each of the alkalies, potash, soda, and ammonia, forms with carbonic acid, a carbonate, consisting of an equivalent proportion of each ingredient; a sesquicarbonate, in which there are one equivalent and a half of acid to one of alkali; and a bicarbonate, in which there are two equivalents of the acid to one of alkali. When saturated with the acid, they are more susceptible of crystallization, and less nauseous to the taste.

The evolution of the acid from the carbonates of lime and ammonia has been already exhibited.

OF BORATES.

The biborate of soda is found in nature in certain lakes, and is known in commerce as borax. In the examination of minerals by the blowpipe, it is very useful.

The other soluble borates, which are those of potash, soda, lithia, and ammonia, are obtained by uniting the acid directly with the base. The borates, which are quite or nearly insoluble, are procured by double decomposition with the borate of soda. Borates are undecomposable by heat, when their bases are undecomposable by that agent. Other borates, when intensely heated, are resolved into oxygen, a metallic radical, and boric acid.

OF SILICATES.

The silicates are procured either by double decomposition, or by heating silicic acid strongly with the base. They are not decomposable by heat alone; although, when heated with charcoal, some of the silicates are converted into silicurets. All the silicates, excepting those of potash, soda, and lithia, are insoluble.

OF CYANATES AND FULMINATES.

The soluble cyanates are decomposable by water, and, if insoluble, by acids, into carbonic acid and ammonia. The fulminates are chiefly remarkable for the violent explosions which they produce by heat or percussion. The fulminate of mercury is employed as priming in percussion gun locks. It may be obtained by the following process: Dissolve 100 grains of mercury with heat in a measured ounce and a half of nitric acid of moderate strength; when cold, mix the solution with a measured ounce and a half of alcohol, and apply heat till effervescence takes place. When red fumes appear, check the action with water. The powder which precipitates, well washed with water, and aftewards dried at a gentle heat, will be the fulminate of mercury.

OF DOUBLE OXYSALTS.

There are many cases in which two salts, formed by different bases but of the same acid, enter into combination. A compound thus constituted, formerly received the appellation of a triple salt, but is now designated as a double salt.

Tartar emetic is a double tartrate, consisting of tartrate of potash combined with tartrate of antimony. See page 404.

Rochelle salt is a compound of tartrate of potash with the tartrate of soda. An analogous compound is formed by the union of tartrate of potash with tartrate of iron, called *ferri et potassæ tartras*, or tartrate of potash and iron, in the United States Dispensatory.; to which excellent work, I refer students for much valuable information which my limits will not allow me to add.

The saline compound, well known under the name of alum, is composed of one atom of trisulphate of alumina, and one of sulphate of potash, besides twenty-four atoms of water of crystallization.

Other double sulphates have been formed analogous to alum, substituting soda or ammonia for potash, or iron, manganese, or chromium for alumina.

Double silicates and carbonates exist in nature. Dolomite is a species of marble, consisting of the carbonates of lime and magnesia in equivalent proportions. Felspar consists of a silicate of alumina and a silicate of potash. Many native crystals, well known to mineralogists, are double silicates.

Glass in general is a combination of one or more silicates. Flint glass, according to Turner, is a double sexsilicate of lead and potash.

It ought not to be supposed that double salts are always produced, by the combination of single salts previously existing separately. In the case of tartar emetic, the bitartrate of potash, containing two equivalents of acid to one of base, is converted into the double tartrate of potash and antimony, by saturating with one equivalent of the sesquioxide of this metal, one equivalent of the acid in the bitartrate. Thus a tartrate of antimony is produced in combination with a tartrate of potash, and a double salt is of course formed.

It appears possible for two double salts to combine, as when biborate of soda (borax) is added to bitartrate of potash, in order to produce the "soluble cream of tartar" of pharmacy. According to Berzelius, this compound may be considered as consisting of a double tartrate of potash and soda (sal Rochelle), combined with a double tartrate of potash, and boric acid acting as a base. See United States Dispensatory, 3d edition, page 606.

SECTION II.

OF SULPHOSALTS.

According to Berzelius, the metallic sulphides, which are capable of combining with each other to form sulphosalts, contain for each atom of radical, the same number of atoms of sulphur, as the salifiable oxybases and oxacids of the same radicals contain of oxygen. In consequence of this analogy in composition, if sulphydric acid gas be transmitted through a concentrated solution of an oxysalt, in which the acid and base have each a metallic radical, the hydrogen of the sulphydric acid takes all the oxygen from both radicals. Meanwhile, an equivalent number of atoms of sulphur, consequently liberated, take the place of the oxygen, forming a sulphosalt, consisting of a sulphacid and a sulphobase, analogous, in the number of atoms of each ingredient, to the oxysalt, from the decomposition of which it originates.

In order, however, to effect the combination of the electro-positive metallic sulphides which act as bases, with the sulphides of non-metallic radicals which act as sulphacids, a different method must be adopted. In the case of sulphydric acid gas, which does not combine, except with the sulphides of the metals of the alkaline earths and alkalies, it is either brought into contact with a carbonate of the base heated to redness, or nade to enter into a solution of the hydrate. Whichever method be ed, no access of atmospheric oxygen should be allowed. In either one portion of the sulphydric acid is decomposed, its hydrogen com- g with the oxygen of the base, and its sulphur with the metal; while her portion of the acid unites with the sulphide thus formed, produc- sulphydrate.

has been stated, page 284, that combinations of sulphocarbonic acid be formed with most of the electro-positive sulphides, either by di- nion, or by double decomposition. There are other methods of pre- g these sulphosalts, of which I cannot treat, consistently with the prescribed for this work.

◆

SECTION III.

OF SELENISALTS AND TELLURISALTS.

has been already stated, both selenium and tellurium are capable of ining with different radicals, forming selenides and tellurides. These, ny cases, like the corresponding compounds formed by sulphur, unite ber to form selenisalts and tellurisalts. The resulting combinations, ver, have been but little studied.

◆

SECTION IV.

OF CHLOROSALTS, BROMOSALTS, IODOSALTS, AND FLUOSALTS OF THE SECOND GROUP.*

e *chlorosalts* are generally obtained by mingling the electro-posi- nd electro-negative chlorides, either in the wet or dry way. In the case, heat must be employed in order to facilitate their union.

e *bromosalts* and *iodosalts* may in general be obtained in the same er, by mingling electro-positive and electro-negative bromides and es.

ave mentioned, in treating of the chlorides of the metals, several in- es in which combinations are formed by them with chlorohydric acid. compounds, however, are rare, and, when they do occur, appear o possess stability.

page 308, I have stated my opinion that the compounds, designated erzelius as fluohydroboric acid and fluohydrosilicic acid, should be dered as tertium quids, in which the fluoride of hydrogen performs art of a base, while the fluorides of boron and silicon act as acids. e fluohydroboric acid is a fluoborate of hydrogen, and fluohydrosilicic a fluosilicate of hydrogen.

ith the fluorides of columbium and titanium, the fluoride of hydrogen

---

* See page 413.

ounds analogous to those abovementioned, and which
fluocolumbate, and fluotitaniate of hydrogen.

y fluosalt like those abovementioned, in which hydr
ical, is brought into contact with an oxybase, of whic
able of forming a fluobase, the hydrogen unites with
gen oxybase, while the radical of this base unites with the
Th of the fluosalt, consequently liberated, combines with
ase.

fluosalts are formed by the direct reaction of the flu
ich compose them, either in the wet or dry way. By
cid to the fluorides of potassium and sodium, fluohy
ob ses may be formed. See letter on the Berzelian no
ure in the Appendix.

* * *

SECTION V.

OF CYANOSALTS.

The cyanosalts are in general obtained either by the direct uni
cyanacid with a cyanobase, or by decomposition. It is by the la
thod that the cyanoferrite of potassium is formed, the sulphate of
toxide of iron being presented to the cyanide of potassium. In
the sulphuric acid, and the oxygen of the protoxide of iron, are tra
to one portion of the potassium. The cyanogen, consequently l
forms with the iron, cyanoferrous acid, which unites with the u
posed portion of the cyanide of potassium. See pages 291, 292,

ORGANIC SUBSTANCES.

Organic substances are all those compounds which are generated in vegetables or animals, or produced by the reaction of the elements of which they consist, either among themselves or with other bodies. They are naturally divided into *Vegetable Substances*, or those derived from the vegetable kingdom, and *Animal Substances*, or those derived from the animal kingdom.

OF VEGETABLE SUBSTANCES.

It is, perhaps, less difficult to acquire some general ideas of vegetable and animal chemistry, than to make an equal progress in the chemistry of inorganic substances. The ultimate elements of vegetable and animal matter are fewer, and are peculiarly well known. But the light which is thrown upon inorganic compounds, by resolving them into their ultimate elements, is much more satisfactory than any which we can, by the same means, extend to organic products. Between these, ultimate analysis can demonstrate little more than a difference in the proportions of the hydrogen, oxygen, carbon, and nitrogen, of which they are constituted; although in their influence on vitality they may display the opposite properties of the most delicious food, or the most deleterious poison, of delighting or offending our senses in the extreme.

Hydrogen, oxygen, and carbon are the principal ultimate elements of vegetable substances. In a few vegetables, nitrogen is a constituent. Potassium, sodium, and calcium, in the state of alkali or earth, with minute portions of iron and of other matter, may also be found in them. But hydrogen, oxygen, and carbon are, in quantity and importance, greatly predominant.

It is generally a marked distinction between organic and inorganic substances, that the latter can, in a much greater number of instances, be imitated by art.

The incompetency of chemists to regenerate the substances analyzed by them, has caused the accuracy of their deductions to be questioned. Rousseau, having heard Rouelle lecture on farinaceous matter, said he would not confide in any analysis of it, till corroborated by its reproduction from the elements, into which it was alleged to have been resolved. I conceive that an acquaintance with facts, thoroughly demonstrable by modern chemistry, would have rendered that ingenious philosopher less sceptical. It may indeed at first view seem reasonable to consider synthesis as the only satisfactory test of the truth of analysis. But, when diamond is burned in one bell glass, and charcoal in another, in different portions of the same oxygen gas, if subsequently in each vessel, in lieu of the diamond and charcoal, carbonic acid is found, from which carbon may be liberated by potassium, who would hesitate to admit both substances to consist of carbon, because this element cannot be recovered from the gaseous state in the crystalline form of diamond?

It does not appear that any vegetable matter is capable of existing as a permanent gas.

Of the Mode in which the Ultimate Ponderable Elements of Organic Substances are associated.

It was originally advanced by Gay-Lussac, and has since been ingeniously sustained by Dumas, that vegetable and animal substances, containing three or more elements, should not be regarded as simple combinations, into which the elements enter singly, but as made up of binary* compounds which unite with each other in virtue of their opposite electrical states, as acids and bases.†

Thus sugar is conceived to be a compound of carburetted hydrogen and carbonic acid, and ether, of etherine and an acid, or water acting as an acid.

It has lately been ascertained by Wohler and Liebig, that there are common radicals not only in analogous substances, but in such as are quite unlike each other, as for instance, *benzule*, consisting of $C^{14}H^{5}O^{2}$, forms, with an atom of hydrogen, oil of bitter almonds, and with an atom of oxygen, benzoic acid. It produces also a chloride, a bromide, and an iodide, with an atom of chlorine, bromine, and iodine respectively.

---

* In the sense in which the word binary is used by Berzelius and many other chemists, a binary compound is one which contains two heterogeneous elementary atoms. By Dalton this word has been used to signify a combination of two atoms of one kind with one atom of another.

† Johnson's Report for 1832, page 497.

Prout supposes that a large class of vegetable products, into which he has ascertained the hydrogen and oxygen to enter in the ratio for forming water, to consist of this liquid and carbon. On this view they are hydrates of carbon. In fact, under this head would be placed almost all vegetable principles which are neither acid, oily, nor resinous; such, for instance, as sugar, starch, gum, and lignin.

Of the Influence of Heat upon Vegetables, with and without Access of Air.

When subjected to distillation, vegetables, in the first place, yield the water and essential oils previously existing in them. If the heat be raised to redness, they afford carbonic and pyroligneous (acetic) acid: also carbonic oxide with bituminous matter, or essential oils formed by the union of the hydrogen and carbon in various ratios, and which are more volatile in proportion as the hydrogen predominates. By further ignition the oils and bitumen, thus obtained, are converted into some of the varieties of carburetted hydrogen; a deposition of carbon being a necessary concomitant of the change. In proportion as the hydrogen is rarefied by heat, its capacity to suspend the carbon appears to be diminished. See page 285.

The oxygen in the vegetable matter, subjected to ignition in close vessels, by uniting with the hydrogen and carbon, gives rise to acetic and carbonic acid, carbonic oxide, and water. These results evidently originate from the superior volatility of the hydrogen and oxygen, which causes them to pass off into the aëriform state, with such portions of the carbon as they may, under these circumstances, be capable of retaining.

The experiments of Sir James Hall show that vegetable matter, simultaneously subjected to heat and pressure, is converted into a bitumen analogous to that of mineral coal. Under these circumstances caloric destroys the organic structure, but does not sever the constituents of many bodies, which would be otherwise partially dissipated. When ignited in the air, it were almost unnecessary to say that hydrogen, oxygen, and carbon must yield water and carbonic acid only. These are the only products of hydrogen and carbon, when burned where there is an ample supply of oxygen.

Of the Effects, upon Vegetable Matter, of Chlorine, Bromine, and Iodine; also of the Alkalifiable Metals, and some of the more powerful Acids.

Chlorine, bromine, and iodine act upon vegetable matter, in consequence of their affinity for hydrogen only; for carbon they have little affinity, and exerting an attraction for oxygen only under peculiar circumstances, in ordinary cases display none.

Where there is much carbon in intimate combination, as in wax and resinous substances, chlorine does not act, until, by heat, the attraction of the hydrogen for the carbon is more or less counteracted. Where water is present, its decomposition is always slowly effected by chlorine; especially when any matter, attractive of oxygen, happens to be present, as in the case of vegetable colouring matter. Hence the efficacy of chlorine in bleaching.

The alkalifiable metals destroy vegetable matter containing oxygen as an essential constituent, by combining with this principle, and liberating hydrogen. When potash and soda are heated to redness with organic substances, they are converted into alkaline carbonates, acquiring the carbon and oxygen requisite to form carbonic acid from the organic matter; but at a temperature of 400°, or 450°, those alkalies produce oxalic acid by the decomposition of the organic matter, and are converted into oxalates.

Fluohydric, fluoboric, and sulphuric acid, at moderate temperatures, destroy organic matter by their attraction for water; in which respect, they evidently do not act as acids, but have an effect analogous to that of the dry alkaline hydrates, and desiccated chlorides.

In like manner, sulphuric acid, hydrate of potash, and chloride of calcium absorb the elements of water from alcohol, and discolour it by evolving carbonaceous mat-

Chlorohydric acid acts feebly on organic substances, but so far as it does act, it appears also to operate by its affinity for water.

Nitric acid, on the other hand, has no other effect than to impart oxygen, giving rise to the same products as combustion. This result ought not to excite surprise; as this acid is, in effect, composed of the atmospheric elements, condensed into the liquid form, and containing an excess of that principle which is the most active. Owing to the volatility of nitric acid, many substances cannot be completely oxygenated by it, unless after several distillations. Repeatedly distilled from sugar, it first produces malic acid,* then oxalic acid, and finally water and carbonic acid. These ultimate results are inevitably consequent to the ignition of the nitrates with dry vegetable substances; as, in this case, the base of the nitrate detains the acid, until the heat is adequate to produce a powerful reaction.

Of the Influence of the Proportions of the Ultimate Elements upon the Qualities of the Substances which they constitute.

It has been suggested by Gay-Lussac and Thenard, that the properties of vegetable substances may be inferred to a limited extent, from the proportions of their ultimate elements. He observes that, no nitrogen being present, if the oxygen be in a greater ratio to the hydrogen than in water, the compound is acid. If the ratio of the oxygen to the hydrogen be less than in water, the compound may be acid, but is generally oily, resinous, alcoholic, or ethereal. If the ratio of these elements to each other be the same as in water, the product is of the nature of sugar, gum, or lignin. To this it may be added that alkalinity in vegetable principles seems to require the presence of nitrogen.

Of the Analysis of Organic Substances.

The analysis of vegetable and animal matter has been latterly accomplished by heating the substance with chlorate of potash, or preferably with oxide of copper, so as to oxidize all the carbon and hydrogen, and liberate, in the gaseous state, any nitrogen which may be present. The hydrogen has been in general estimated from the water produced; the carbon, from the quantity of carbonic acid. Hence the products of the operation have been first passed over chloride of calcium, and afterwards subjected to hydrate of potash, lime-water, or alkaline solutions. The water is estimated from the increased weight of the chloride, and the carbonic acid by the volume absorbed.

---

* It has lately been alleged that a peculiar acid is produced, which has been mistaken for malic acid.

ORDER PURSUED IN TREATING OF VEGETABLE SUBSTANCES.

It is conceived that vegetable substances, and the processes and products resulting from their chemical reaction, may be treated of advantageously under the following heads, in the order in which they are mentioned:—1. Vegetable substances which are neither acid, alkaline, oily, resinous, nor volatile; 2. Oils; 3. Resins; 4. Gum-resins; 5. Naphtha, petroleum, bitumens, amber, and mineral coal; 6. Vegetable acids; 7. Vegetable alkalies; 8. Doubtful vegetable alkalies; 9. Vinous fermentation; 10. Ethers; 11. Acetous fermentation.

SECTION I.

OF VEGETABLE SUBSTANCES WHICH ARE NEITHER ACID, ALKALINE, OILY, RESINOUS, NOR VOLATILE.

Under this title will be noticed *gum* and *mucilage*, *sugar*, *fecula* or *starch*, *gluten* and *vegetable albumen*, *indigo* and *indigogene*, *caoutchouc* or *gum elastic*, *lignin*, and *cork*.

OF GUM AND MUCILAGE.

The obvious properties of gum must be familiar to every body, as observed in the solution of gum arabic in water. Solubility in water, with insolubility in alcohol, is an essential characteristic of gum. In ether it is insoluble. It is neither sweet nor sour. By nitric acid it is partially converted into mucic acid.

Gum is separated from water in a thick curdy precipitate by subacetate of lead.

It causes the oxides of antimony and bismuth to remain in solution, when otherwise they would be precipitated by water as sub-salts.

Substances, of which gum is the generic appellation, agree in certain general properties; but there are, perhaps, scarcely two exactly alike. They appear to vary with the plant or tree to which they owe their production.

Gum and mucilage were, until latterly, supposed to be solid and liquid forms of the same matter, but are now considered as differing in their chemical properties. Gum is soluble in water, whether hot or cold; while mucilage is insoluble in cold water, and but little if at all soluble in hot water. When subjected to this liquid at a boiling heat, mucilage swells prodigiously, and so far unites with the water, as to make a thick paste, or a glutinous liquid.

Gum arabic is considered as the most perfect specimen of the principle called gum. Berzelius considers the reaction of a solution of this substance with a solution of the silicate of potash, as the most characteristic of its properties. One portion of it forms with one part of the alkali and all the acid, a triple compound which precipitates; while another portion of the gum and the remainder of the potash combine and remain in solution.

Gum arabic differs from other gums in combining with the sesquioxide of iron, and forming a compound insoluble in water, but soluble in acids. A solution of gum arabic in 1000 parts of water, being mixed with a solution of the sesquioxide of iron, yields, in 24 hours, a yellow precipitate. This species of gum also combines with, and precipitates the protoxide of mercury from the nitrate.

Of mucilage, infusions of gum tragacanth and flaxseed are deemed the best specimens. From the bark of the slippery elm, and the pith of sassafras, especially the latter, very superior species of mucilage are obtained.

"Guerin has published an elaborate examination of the gums. He divides them into three classes: 1. *Arabin*, of which gum arabic is the type, soluble in cold water; 2. *Bassorin*, which swells into a jelly, but does not dissolve in water: Bassora gum is the type of this class; 3. *Cerasin*, from the gum of the cherry-tree (*Cerasus*) is also insoluble in cold, but soluble in boiling water, and when treated with nitric acid, gives about *one-fourth* less mucic acid than bassorin.

"*Arabin*, by his analysis, consists of carbon 48·81, hydrogen 6·2, oxygen 49·85, nitrogen 0·14 = $6C+5H+5O$.

Gum senegal, and the soluble parts of gum tragacanth and bassora gum, consist of arabin.

"*Bassorin* = carbon 37·28, hydrogen 6·85, oxygen 55·87 = $10C+11H+11O$.

"*Cerasin* appears to be metamorphic arabin; for it has precisely the same composition, and is changed into it by solution in boiling water. The gums of the cherry, apricot, prune, peach, and almond-tree, are of this kind."*

OF SUGAR.

Under this head I would place two genera of substances; crystallizable sugars, and syrups incapable of crystallization. Of the former, sugar candy, and the crystals found in raisins and honey, are specimens. The latter are exemplified by the uncrystallizable syrups of raisins and of honey; also the sweet matter of the sweet potato, and molasses, called the uncrystallizable syrup of the sugar cane. I conceive sweetness to be an indispensable attribute of sugar.

The qualities, both of crystallizable and uncrystallizable sugars, vary with the plants from which they are produced. In the power of imparting sweetness to infusions, the crystallizable sugar of the cane is pre-eminent.

In manna, which is the concrete juice of a species of ash (Fraxinus ornus), there is a peculiar crystallizable sugar, called *mannite*. In mushrooms, also, a peculiar sugar is said to exist.

Sugar is soluble in about an equal weight of cold water. Above a boiling heat, it becomes a liquid per se, dissolving in its water of crystallization. Alcohol dissolves one-fourth of its weight of sugar.

Berzelius observes that, judging from the experiments which have hitherto been made, sugar does not combine with any salt, but reacts with many metallic salts. Yet he alleges that its aqueous solution dissolves the carbonate and subacetate of copper, giving rise to a green liquid, from which the metal may be precipitated by sulphydric acid, or cyanoferrite of potassium, but not by alkalies. When boiled with solutions of cupreous salts, it causes the reduction of the copper.

---

* Johnson's Report for 1832, page 511.

OF FECULA OR STARCH.

A substance, of which starch is a good specimen, and of which the generic name is fecula, may be obtained from the meal or flour of grain, and from the roots of the potato and other vegetables. It is more or less a constituent of vegetables in general. When the farinaceous matter, procured from such sources by rasping or grinding, is washed, the fecula is suspended and subsequently deposited.

It was discovered by Leeuwenhoeck, with the aid of a microscope, in 1716, that starch consists of globular grains, each enveloped in a tegument, pocket, or sac, differing from the internal mass. In 1825, these observations were confirmed and extended by Raspail, who also observed that the envelop or tegument was insoluble in water, while the interior portion was soluble in this liquid. He also ascertained that the globules which constitute potato starch, do not exceed in diameter one-eighth of a millimetre; those of wheat starch do not exceed one-twentieth of a millimetre, nor those of starch from millet, $\frac{1}{400}$th of a millimetre. As, according to Payen and Persoz, the tegument does not form more than four or five thousandths of the weight, the internal portion may be considered as characterizing the whole, uninfluenced, to any important extent, by the tegumentary matter.

In the case of wheat, and other grain of a like nature, fermentation is requisite to liberate the fecula from other matter.

Fecula forms a black colour with a great quantity of iodine, a blue with less, and a violet with still less. It does not combine with cold water, but forms a viscid solution with hot water. It is neither dissolved nor acted upon by alcohol or ether.

Fecula dissolves in cold nitric acid; but, when heated with it, yields oxalic acid. A slight torrefaction changes its nature, so that it may be used as a substitute for gum. Triturated with potash, fecula acquires the property of dissolving in cold water. The solution is clouded by acids.

Its solution in hot water is precipitated by subsalts of lead, and in cold water by an infusion of galls.

Of the Conversion of Fecula into Dextrine and Raisin Sugar.

Boiled with diluted sulphuric acid for about thirty-six hours, fecula is converted into sugar. A similar change is alleged to have ensued partially in starch, which was made into a paste with twelve times its weight of boiling water, and kept for two years. By the addition of gluten, and the application of a heat between 122° and 167° F., a similar result is said to have been attained in about ten or twelve hours.

It is well known to those who are acquainted with the manufacture of whiskey from grain, that a portion of malt is necessary to render the wash or wort susceptible of the vinous fermentation, and that the product is much affected by the circumstances under which the infusion of the grain is accomplished. More than twenty years ago, my late friend, Col. Anderson, who had distinguished himself by his ingenuity and sagacity in improving the processes and apparatus of our American distilleries, observed to me that the mixture of grain and water became sweeter towards the close of the process of infusion, and that he believed a chemical change was induced, by which more or less sugar was generated. This inference of our ingenious countryman has been fully justified by the researches of Payen and Persoz, of Paris, whence it appears that, by digestion with malt, fecula is partially changed into raisin sugar, and partially into a soluble substance called *dextrine*, from a peculiar influence which it exercises upon the plane of polarization, during the reflection of light.

The property of saccharifying, thus existing in malt, has been traced to a peculiar principle called *diastase*, which exists therein, in a proportion not exceeding a five-hundredth part. It is obtained by moistening ground malt with half its weight of water, and exposing the mass to pressure. The exuding liquor is mingled with a quantity of alcohol, sufficient to remove viscidity, and next filtered. The liquor resulting is then subjected to alcohol of 340°, by which the diastase is thrown down impure. By three successive solutions in water, and precipitations by the same means, also subsequent exposure on a glass pane, in thin layers, to a current of air of about 120° F., pure and dry diastase is obtained in the state of a white amorphous solid matter.

Diastase does not alter gum, sugar, gluten, nor albumen, nor the teguments of fecula, but operates surprisingly on fecula proper, in changing it more or less into sugar. This change is effected without any absorption of the air, or any evolution of gaseous matter, and takes place either in pleno or vacuo.

One hundred parts of starch, mingled with 39 parts of water at about 90° F., afterwards mixed with 6.13 parts of diastase, dissolved in 40 parts of cold water, and digested for an hour at a temperature between 90° and 100°, gave 86.91 parts of sugar.

The starch is never entirely converted into sugar at one operation, a portion being brought only to the intermediate state of dextrine. Yet by removing the sugar by alcohol, and renewing the reaction with the diastase, the whole of the fecula may be saccharified, if I may be allowed to use this word, trusting to analogy rather than authority for justification.

According to Mr. Caventou, by exposure to a temperature a little above 212°, dry starch acquires a slightly red tint, and emits the odour of baked bread. The modification which it sustains, under these circumstances, is analogous to that which ensues when it is gelatinized by hot water. In this state, it has been considered as a hydrate of fecula; but it is alleged by him that the jelly cannot be restored to its original state. He regards it as essentially the same substance as that which T. de Saussure has designated as *amydine*. The blue colour produced by iodine with starch, Mr. Caventou considers as the characteristic effect of amydine.

When starch is exposed to a temperature higher than is necessary to convert it into amydine, it becomes more soluble in cold water, and produces, with iodine, a purple colour.

Amydine forms an insoluble compound with protoxide of lead, when digested with the subacetate.

Besides gluten and fecula, barley is alleged to contain a principle, called *hordein*, resembling sawdust in its external characters, and supposed by Dr. Thomson to be only a variety of fecula.

Hordein is supposed to be converted, during the malt-ing process, into sugar and starch. This conjecture is much strengthened by the discovery, that lignin, to which hordein is most analogous, may be converted into sugar.

Of the Composition of Gum, Sugar, and Starch.

The proportions in which hydrogen, oxygen, and carbon exist in gum, sugar, and starch, are nearly the same. Gum and sugar may be deemed compounds of carbon with water; as, in either, the hydrogen and oxygen are in the proportion necessary for forming that liquid. Gum may also be considered as a compound of carbonic oxide with hydrogen; as it is said to contain an equal number of the atoms of each ultimate element.

In sugar, there is a small excess of carbon.

The composition of starch differs but little from that of gum and sugar.

According to Dumas, the composition of anhydrous sugar is such, that it may be represented by a compound of carbonic acid and etherine. Hence it would correspond with the probable composition, though not with the properties of carbonic ether, supposing the existence of such an ether to be possible.

Agreeably to an analysis made by Opperman, the composition of manna sugar accords with that which is assigned to gum.

OF GLUTEN AND VEGETABLE ALBUMEN.

Plants contain substances which have been designated as vegeto-animal, on account of their analogy with the white of egg, and the fibrin of animal matter. Nitrogen is always an ultimate element in them, and occasionally sulphur and phosphorus. As they are to be found in all vegetables to a greater or less extent, it appears proper to arrange them under the head of the general principles of vegetables, although in a majority of vegetables, only very minute quantities are to be detected. The glutinous mass which remains when wheat flour is kneaded in a bag under water, had received the name of gluten. Latterly this mass has been separated into two distinct principles; one of which retains the name of gluten, while to the other, the appellation of vegetable albumen has been given, on account of the coagulation of its aqueous solution by heat. By Einhof and Taddei, it was ascertained that the mass called gluten, as abovementioned, was partly soluble, and partly insoluble in boiling alcohol. The soluble portion Taddei called *gliadine*, the insoluble portion *zimome;* but Berzelius designates the former as gluten, the latter as vegetable albumen.

Vegetable albumen is found in all those products of vegetation which yield emulsions when triturated with water; as, for instance, in almonds, in which it is in a state of combination with an oil. It exists in all vegetable juices which are coagulated by heat.

It is not adhesive. By desiccation it becomes opake. Caustic alkalies dissolve it readily, having their causticity diminished. By a great excess of acid it precipitates from the solution, but not otherwise; although the acid predominates sufficiently to redden litmus. When precipitated by an excess of acid, it subsides in combination with the acid, and may be redissolved by pure water, but not by a diluted acid. From the last mentioned solution, the albumen is precipitated very readily by the cyanoferrite of potassium, or the bichloride of mercury.

It is to destroy the gluten and vegetable albumen, that fermentation is required in the manufacture of starch.

Gluten is distinguished by its approaching more to the nature of animal matter, than any other product of vegetation, excepting vegetable albumen. In consequence of the presence of nitrogen, it yields ammonia by distillation. It is to the presence of gluten in wheat, that its pre-eminence in nutritive power is attributed.

To the glutinous property of this substance, dough is supposed to owe its rising, during the process of panification, after being mixed with leaven or yeast.

The cellular part of leavened bread is indebted for its existence to gluten, which, by confining the gaseous matter arising from an incipient fermentation, is inflated into innumerable cavities.

Gingerbread owes its cellular structure to a different process. Among its ingredients are molasses and pearlash, the latter consisting of potash and carbonic acid. By the fermentation of the flour and molasses, an acid is generated, which, combining with the potash, liberates the carbonic acid. This gas, by expanding within the dough in consequence of the heat of the oven, causes innumerable cavities, resembling those produced in the ordinary process of panification.

Probably a bicarbonate would cause the rising of gingerbread better than pearlash, as it would yield double the quantity of gas.

A bicarbonated alkali is found to act as a leaven in cakes, when old cider is mingled with the dough. No doubt lemonade would answer the same purpose.

Farinaceous matter, destitute of gluten, can only be made into heavy cakes, as exemplified by those of Indian meal.

One of the principal defects of bread, is sourness, arising from acidity in the yeast. This may be easily removed by pearlash, or a filtered infusion of clean ashes. Carbonate of ammonia is also used by bakers, and probably promotes the lightness of the bread by its vaporization.

OF INDIGO AND INDIGOGENE.

According to Liebig, the blue colouring matter of the crude indigo of commerce, consists of a substance which he calls indigogene, and oxygen. He conceives that indigogene pre-exists in the plants, and, when pure, is white. When the indigo plant is macerated in water, the indigogene, being soluble in that liquid, is dissolved, and by the oxygen of the air is converted into indigo blue, which is insoluble. This substance is deoxidized by the dyer, by means of green vitriol and lime. While thus rendered soluble, and yellow in colour, the indigogene unites with the cloth, and, regaining its oxygen and its insolubility by exposure, dyes the cloth permanently blue.

Indigo is soluble in concentrated sulphuric acid, especially that of Nordhausen. Berzelius alleges the resulting combination to be productive of two acids.

Indigotic acid is produced by the reaction of nitric acid with indigo.

OF CAOUTCHOUC OR GUM ELASTIC.

Caoutchouc exudes, in the fluid state, from certain plants, and congeals in the form of the mould on which it may be received. It is a most singular substance, on account of its peculiar elasticity; whence its popular name abovementioned. It is insoluble either in water or alcohol, but dissolves in ether or the volatile oils, especially those of turpentine, sassafras, cajeput, and naphtha. When recovered from its solution in these oils by evaporation, it does not fully regain its elasticity; but it is said to recover this property when precipitated from cajeput oil by alcohol. It burns with a bright flame, especially in oxygen gas. After a length of time, it is acted on by alkalies and fixed oils; and, merely by the mechanical compression of a tight bandage, undergoes a species of disorganization, rendering it more adhesive and less elastic.

It yields ammonia by distillation, and of course contains nitrogen. It becomes warm when suddenly extended.

The great inflammability of caoutchouc has been illustrated, page 155.

By exposure to heat, not much above that of boiling water, caoutchouc fuses into a viscid liquid of the consistency of tar. In undergoing this change, it does not necessarily lose any weight, but is irretrievably deprived of the organic structure to which it owes its elasticity. By distillation, and careful rectification of the products, Messrs. Enderby, of London, have procured from caoutchouc, a liquid as volatile as hydric ether, and of the specific gravity of 0.64, so that it is peculiarly light. To this artificial naphtha the name of *caoutchouchine* has been given. It is colourless and inflammable, soluble in alcohol, and a solvent not only of resins, but also of caoutchouc, which is deposited from it by evaporation unchanged. It would seem, therefore, that artists will no longer have to complain of the want of a good solvent of that useful and wonderful product of vegetation.

It has been ascertained by Dr. Mitchell that caoutchouc bags, after soaking in a mixture of ether and alcohol of the specific gravity of from 750° to 780°, or the usual officinal strength, may be inflated with air, and the material of which they consist consequently extended to various degrees of tenuity, according to the peculiar character of the variety subjected to trial. Hence it may be used to make balloons, gas bags, or sheet gum elastic, which is very useful for fillets, with which to make air-tight junctures or lutings. There is no better mode of joining a tube to the tubulure of a retort, or receiver, than by tying about the tubulure the body of a small caoutchouc bag, while the tube is inserted into the neck, and carefully secured by a ligature. Fused caoutchouc is useful in some cases as a lute. It will not, however, resist fuming nitroso-nitric acid. I have observed that it takes fire when subjected to that acid.

Dr. Mitchell has made some very interesting observations respecting the power of gases to pass through thin membranes of caoutchouc. By some inconceivable process, gases, which are all prone in a greater or less degree to reciprocal intermixture, will effect this result, notwithstanding the interposition of caoutchouc, and the opponent influence of great pressure.

When a vessel filled with atmospheric air, and having the mouth closed by a caoutchouc membrane, was introduced into a vessel of hydrogen, this gas made its way into the vessel, until the membrane burst outwards; but when the vessel, while similarly closed by the membrane and replete with hydrogen, was exposed to common air, the hydrogen escaped until the membrane burst inwards. A tube, with a trumpet-shaped mouth, being bent so as to form a syphon, and the larger orifice closed by the membrane while full of atmospheric air, a suitable quantity of mercury was poured into the syphon, until it stood in both legs at the same height. Under these circumstances, when the membrane was brought into contact successively with different gases, they were found to enter with various degrees of celerity, as will appear from the following statement:—

	H.	M.
Ammoniacal gas - - - -	0	1
Sulphydric acid - - - -	0	2½
Cyanogen - - - - -	0	3¼
Carbonic acid - - - -	0	5½
Protoxide of nitrogen - - -	0	6½
Arseniuretted hydrogen - - -	0	27½
Olefiant gas - - - -	0	28
Hydrogen - - - - -	0	37¼
Oxygen - - - - -	1	13
Carbonic oxide - - - -	2	40
Nitrogen - - -	3	15

The gases continued in some instances to enter until the mercury in the longer leg rose to the height of sixty inches.

These results appear to me wonderful, and their attainment does great honour to the sagacity and ingenuity of the author. It is quite surprising that the atoms of ammonia should pass through the membrane with greater celerity than those of hydrogen, when each of the former consists of three of the last mentioned gas, united with one atom of nitrogen. Also that two atoms of oxygen, while associated with an atom of carbon, should permeate the membrane more speedily than an isolated atom of oxygen.

It also appears from experiments made by Dr. Mitchell, and repeated by myself, that caoutchouc is probably more highly susceptible of electric excitement, than any other organized body; and probably is at least equal in excitability to any inorganic substance.

OF LIGNIN.

The insoluble, tasteless, inodorous, and tenacious fibres of wood, hemp, or flax, have been distinguished as a peculiar vegetable substance, called lignin.

From the experiments of Mr. Braconnot, it appears that lignin may be converted into gum or sugar, by means of sulphuric acid. Some linen rags were triturated with concentrated sulphuric acid, until the fibres disappeared. The resulting mixture being diluted with water, and the acid saturated with chalk, the aqueous solution, when separated by the filter and evaporated, yielded a species of gum, in weight exceeding the linen employed. When instead of saturating the acid with chalk, as abovementioned, the mixture of acid and mucilage, produced by the reaction of the acid and lignin, was diluted with water, and boiled for about ten hours, the acid then saturated, and the liquor afterwards filtered and evaporated, crystals of a sugar, resembling the sugar of raisins, were obtained.

By reducing the fibres of wood, previously subjected to boiling water to remove every thing soluble in that liquid, to a state of minute division, and subsequently exposing them to the heat of an oven, they are converted into a flour capable of forming either a nutritious jelly, or bread sufficiently good to be eaten.

The specific gravity of lignin is greater than that of water, the apparent lightness of wood being due to its pores.

OF CORK.

Cork is considered as a distinct principle, as its very peculiar mechanical qualities would indicate. It forms, by the action of nitric acid, a peculiar acid, called *suberic acid.*

SECTION II.

OF OILS.

Oils are divided into *fixed* and *volatile*. Oleaginous substances, like olive oil, castor oil, fat, lamp oil, which cannot be distilled unaltered, are called *fixed oils;* while those are called *volatile*, which, like the oil or spirit of turpentine, petroleum, cajeput, &c., may, without change, sustain the process of distillation.

The inspissation observed in oils, whether fixed or volatile, during exposure to the air, is generally ascribed to their oxygenation. It seems to me probable that oxygen acts by converting hydrogen into water which evaporates.

It was suggested by Dr. Henry, of Manchester, that this absorption of oxygen accounts for the unhealthfulness of newly painted rooms. It appears to me that the breathing of one person would consume more oxygen than the paint of any common room.

I think it probable that the vapour which, by its escape, causes the hardening of the paint, carries off a minute portion of the pigment. That something is volatilized, is perceptible by the smell.

OF FIXED OILS.

Among the most remarkable of the vegetable fixed oils, are those of the olive, of linseed, of poppy seed, and rape seed. Being procured by expression, they contain mucilage. To the presence of this, their liability to become rancid has been ascribed. Rancidity I suppose to arise from a sort of slow combustion, during which oxygen is absorbed. It is not improbable, however, that the oxidizement of the oil may be accelerated by the decomposition of the water in the mucilage.

Fixed oils owe their colour in part to some extraneous matter, which may be removed by charcoal. They are heavier than alcohol, and lighter than water, and are more or less soluble in ether, especially castor oil. Linseed and olive oil are soluble in alcohol, which has been deprived of water by pearlash. Castor oil may be dissolved in any proportion in alcohol thus strengthened. The temperatures at which differe[illegible]eze, are very various; and every oil appears to be decomposable by heat or refrigeration, into a less fusible and more fusible oil. Hence, in cold weather, a portion of the oil of olives may be seen congealed, while the remainder is still liquid.

The soaps which the fixed oils generate with the alkalies are well known, and pre-eminently useful. I stated above, that all of them appear to be decomposable by heat or refrigeration, into a less fusible, and a more fusible portion. It appears, from the experiments of Chevreul, that vegetable and animal oils are composed of two different matters, both soluble in hot alcohol; but one of them, much less so in cold alcohol. Hence, by the agency of this liquid, he was enabled to separate them. The less soluble substance is called *stearin*, and the other *elain*. These, in the process of saponification, give rise to two or three acids, which, combining with the alkali, constitute soap. The acids produced by stearin, are called *margaric*, and *stearic;* that formed by elain, *oleic*. Another matter is at the same time liberated in small quantity, called the *sweet principle of oils*, or *glycerine*.

With soda, oils form hard soap, with potash, soft soap; but the one is made to produce the other by the addition of chloride of sodium. The chlorine unites with the potassium, and the sodium with the oxygen and acids which the potassium abandons.

Water is said to be hard, when it curdles a solution of soap. This quality usually arises from the presence of sulphate of lime, or chloride of sodium, or both.

Sulphur and phosphorus are soluble in fixed oils. An important distinction is to be recollected, existing between what are called *drying oils*, and those which are devoid of the property thus indicated. Linseed oil is rendered drying by boiling it with the oxides of lead.

It has been suggested that the oil is deprived of mucilage during this process; as an affinity is known to subsist between mucilage and the protoxide of lead. Without the property of drying, fixed oils could not be used in varnish or in paint.

The fixed oils, when distilled, yield a volatile oil and carburetted hydrogen; carbon remaining in the retort. The volatile oil, thus obtained, is formed during the process. By combustion in the open air, or with oxygen, fixed oils are converted into carbonic acid and water. They consist of carbon and hydrogen, and a small proportion of oxygen. Nitric acid acts with great energy on them, and, by imparting oxygen, renders them thicker. Chlorine has, indirectly, the same effect. Probably by removing hydrogen, it increases the proportion of oxygen in the compound.

The fixed oils, especially the drying oils, have the property of inflaming with nitric acid, and of entering into combustion with lampblack, or other light carbonaceous matter; also with cotton, wool, and flax. Inflammation has been alleged to arise from their admixture with ashes.

Wax.—This substance, which is considered by modern chemists as a concrete fixed oil, is generally a product of vegetation. It covers leaves and fruits, and constitutes, principally, the pollen of flowers. Being thus extensively produced by vegetation, beeswax was supposed to be collected, not secreted by the insects, through whose instrumentality it is obtained. It has since been advanced by Huber that bees which have access to nothing but sugar, can produce wax; and Oppermann has alleged that pure vegetable wax differs from beeswax in composition.

There are considerable differences in wax, as to fusibility, colour, &c. White wax is produced by a bleaching process, analogous to that by which linen is whitened. It is exposed in thin laminæ to chlorine or the air.

Wax is insoluble in water. Boiling alcohol dissolves about one-twentieth of its weight. It retains, on cooling, only $\frac{1}{100}$th, and this precipitates on adding water. Ether, when boiling, takes up one-twentieth. The alkalies convert it into a species of soap. Acids do not act on it. Hence it is of great use to defend corks, and other substances exposed to them. It is the best material for candles, owing to its yielding a tolerably pure carburetted hydrogen, and being less fusible than tallow.

According to Dr. John, wax consists of two different principles, of which one is soluble, the other insoluble in alcohol. To the former he has given the name of *cerin*, to the latter that of *myricin*.

OF VOLATILE OILS.

The volatile or essential oils, with the exception of those from the rinds of lemons and oranges, which are procured by expression, are separated from the vegetable substances in which they exist, by distillation with water. In consequence of the attraction between the aqueous particles, and those of the volatile oils thus procured, the latter pass into the state of vapour at a much lower temperature, than that at which they would boil per se.

The volatile oils have usually a penetrating smell, and an acrid taste. When pure, they may be evaporated from a pane of glass without leaving a stain.

They unite with alkalies with great difficulty. They are soluble in alcohol, but not in water. Concentrated nitric acid inflames them. According to Henry, some of them detonate with chlorates, and take fire in chlorine.

It will be seen, page 445 that great antiseptic properties have been ascribed to kreosote. I believe these will be found in all the volatile oils, and other acrid volatile principles. I found that for preserving milk, the oils of cloves, cinnamon, and cassia were at least equal to kreosote. About an ounce of milk was preserved from curdling, for several days in summer by the oil of cinnamon. Probably the influence of the essence of spruce in preserving beer is due to volatile oil.

The volatile oils dissolve sulphur, forming compounds formerly called *balsams of sulphur*. Phosphorus is likewise soluble in these oils to a small extent.

The composition of the volatile oils has been variously represented by different chemists. Berzelius divides them into two classes—those which contain, and those which do not contain oxygen. In the latter class he places only the oils of turpentine, lemon, and bergamot. Dumas excludes the oil of bergamot from the class devoid of oxygen, but includes the oil of roses.

The oil of turpentine is the most useful of the volatile oils, mainly on account of its cheapness. It consists, according to the recent analysis of Dumas, when perfectly pure and free from water, of ten atoms of carbon and eight of hydrogen. Pure oil of lemons, now called *citrene*, is composed, according to the same chemist, of five atoms of carbon and four of hydrogen; so that it is *polymeric* with the oil of turpentine.

According to Dumas, the heavy essential oils differ from the light, principally in containing more oxygen and in acting as acids; while the latter act as bases. He considers the oil of cloves, which is one of the heavy essential oils, as consisting of 20 atoms of carbon, 13 of hydrogen, and 5 of oxygen.

A substance called *caryophyllin* has been procured from this oil, which derives some importance from being polymeric with native camphor.

The oil of mustard, another heavy essential oil, presents a very complicated composition. It is, according to the analysis of the abovementioned chemist, composed of carbon, hydrogen, nitrogen, oxygen, and sulphur, in proportions which I shall here express, for the sake of brevity, by the following formula; $C^{32}H^{20}N^{4}O^{5}S^{5}$. He is of opinion that the oxygen and sulphur perform the part towards a compound radical consisting of carbon, hydrogen, and nitrogen, which is more generally performed by oxygen alone; or in other words, that the sulphur supplies the place of a certain quantity of oxygen.

Camphor.—This substance is considered as a concrete volatile oil, which, from its affinity for air, evaporates below the temperature at which it fuses. It is distinguished by forming an acid, instead of being inflamed by the action of heated nitric acid. To produce this result, the camphor is repeatedly distilled, with four times its weight of nitric acid. At a more moderate temperature, this acid dissolves camphor, forming what is called oil of camphor. Chlorohydric and other acids also dissolve this substance. Sulphuric acid and camphor reciprocally decompose each other.

Camphor is composed, according to the analysis of Dumas, of ten atoms of carbon, eight of hydrogen, and one of oxygen.

Artificial Camphor.—If one hundred parts of oil of turpentine, refrigerated by snow and salt, be saturated with chlorohydric acid gas, by means of an impregnating apparatus, a quantity of the gas, equal to about one-third of the weight of the turpentine, is absorbed. Meanwhile the turpentine is changed into a soft crystalline mass, from which, allowing it to drip for some days, about twenty parts of a colourless acid liquor are obtained, charged with many crystals, and one hundred parts of a white, granular, crystalline substance, which so much resembles camphor in odour and volatility, that it has received the same appellation.

Artificial camphor is lighter than water. It does not redden litmus. It may be sublimed, but not without partial decomposition. If passed through an incandescent tube, it is resolved into its constituents. It dissolves in alcohol, and is precipitated from it by water unchanged. Chlorine is disengaged from it by nitric acid.

This substance has been analyzed both by Dumas and Oppermann. According to the former chemist, it is composed of one volume of chlorohydric acid, united to one volume of a compound, formed of ten atoms of carbon and eight of hydrogen.

When a mixture of artificial camphor and quicklime is distilled, a liquid is obtained, which has, according to Dumas, the smell and properties of oil of turpentine, and which he calls *camphene.* If chlorohydric acid be passed through this liquid, artificial camphor is reproduced, which may therefore be considered as a chlorohydrate of camphene. Hence camphene would appear, like etherine and several other compounds of carbon with hydrogen, to act both as a radical and as a base; since the composition of native camphor is such, that it may be represented by one atom of camphene and one of oxygen, and camphoric acid may be considered as a compound of one atom of camphene and five of oxygen.

Camphene is considered by Dumas as identical with ***pure*** oil of turpentine in composition and properties.

When chlorohydric acid is passed through the essential oil of lemons, a substance is obtained analogous to that produced by the action of the same gas on oil of turpentine. Dumas has found, on analyzing this product, that it consists of chlorohydric acid united to a compound of carbon and hydrogen, polymeric with camphene; since a volume of its vapour, though consisting of the same elements in the same proportion as camphene, contains but half as much of each.

This compound, for which Dumas proposes the name of ***citrene***, may be isolated by distilling the artificial camphor made from the essential oil of lemons with quicklime. Citrene is a colourless limpid liquid, possessing the odour and properties of the essential oil of lemons, with which it is identical in composition. Dumas considers that it bears the same relation to the ordinary essential oil of lemons, as camphene does to oil of turpentine; that it is, in fact, the ***pure anhydrous*** oil of lemons.

According to Dumas, crystals may be obtained, by refrigeration, from some varieties of the oil of peppermint, and from the oil of aniseed, which he considers as bearing the same relation to the compounds of carbon and hydrogen existing in those bodies, as natural camphor does to the camphene of oil of turpentine. The crystals obtained from the oil of peppermint, consist of an atom of oxygen, united to a compound consisting of ten atoms of carbon and ten of hydrogen; those from the oil of aniseed, of an atom of oxygen, united to another compound of carbon and hydrogen, containing ten atoms of carbon to six of hydrogen.

The analogy, however, cannot be considered as perfect, until natural camphor shall be obtained by oxidizing the oil of turpentine.

Paraffine and Eupione.*—These substances are obtained from the tar which results from the distillation of organic substances. If animal substances be used, the eupione exceeds the paraffine in quantity, but if vegetable substances be employed, the paraffine predominates.

Paraffine is a white crystalline inflammable body, soft to the touch, and capable of being elongated and bent. It melts at 100°, and volatilizes at a higher temperature without alteration. It is composed of carbon and hydrogen, and contains of each the same number of atoms. It appears to possess the singular property of not being affected either by acids or alkalies.

Eupione is a colourless, transparent, inflammable, insipid, and inodorous liquid. It boils at 336°, and distils without change. It is so remarkably expansible, that in passing from 66° to its boiling point, it increases in bulk one-fifth.

Kreosote.*—This name has been given to an essential oil resulting from the destructive distillation of vegetable matter. It is represented as highly interesting and important, on account of its efficacy as a medicine, and in preserving meat; being in fact considered as the principle to which pyroligneous acid and wood smoke are indebted for their antiseptic powers, and tar-water for its medicinal virtues.

Kreosote is elaborated either from crude pyroligneous acid, or from wood tar, by a series of distillations, and subjection to different agents,

---

[*] I have placed *paraffine*, *eupione*, and *kreosote* under the head of volatile oils, as approaching nearer in properties to these substances, than to any other class of bodies. B.

which resemble much more the operations of the alchemists, than those of the enlightened chemist of the present time. I am confident that before long a much more simple process for its extrication will be devised.

Besides its activity in medicine, kreosote is alleged to have energetic powers as a chemical agent. It is an oleaginous, colourless, transparent, and highly refracting liquid. It has the smell of crude pyroligneous acid or of smoked meat, and its taste is caustic and burning. To the touch it is a little greasy, and its consistency is similar to that of the oil of almonds. It is rather heavier than water, being of the specific gravity of 1.037. It boils at 397°.

[Kreosote is devoid of acid or alkaline reaction. With water it forms two combinations—one a solution of 1 part of kreosote in 400 of water, the other, a solution of 1 part of water in 10 of kreosote. It unites in all proportions with alcohol, ether, and naphtha, and is capable of dissolving a large quantity of iodine and phosphorus, and likewise sulphur, especially when assisted by heat.]

Agreeably to Thenard, the composition of kreosote is expressed by the formula, $C^{14}H^{9}O^{2}$.

* * *

SECTION III.

OF RESINS.

According to Dr. Henry, resins are the inspissated juices of certain plants. I should prefer to say, that resins exist in the juices of certain plants, in union with essential oils, which exuding in union with them and afterwards evaporating, the resins remain in concrete masses. They are also separated from their volatile oils by distillation.

Resins cannot be distilled without decomposition. They are dry, brittle, inflammable, and insoluble in water; but are generally soluble in alcohol, ether, essential oils, alkalies, and acids. Probably with various degrees of facility, they may all be combined with fixed oils.

Copal is not soluble in alcohol, unless camphorated. At a temperature sufficient for its fusion, if copal be dropped into linseed oil, equally heated, a compound is formed, which, exposed to the air, gradually hardens, and forms an excellent varnish.

Common rosin, or resin, exudes from various pines, especially the *Pinus australis*, in union with oil of turpentine, which is distilled from it.

It seems more proper to use the word *rosin* to designate this species; since the formerly synonymous word, *resin*, has been applied to the genus, which rosin exemplifies in all the most prominent properties.

Strong sulphuric acid decomposes resins. Nitric acid, by long digestion on them, produces a substance analogous to tannin. They are dissolved by acetic acid, and precipitated from it by water. When dissolved in turpentine, alcohol, or drying oils, resins are of much use in varnishing.

OF ACID RESINS.

"The resins and gum-resins have been much investigated, and with great success, by Unverdorben. In a series of elaborate memoirs he has shown that many of the known resins are mixtures of several substances of the same class, which may be separated from each other generally by the action of alcohol and ether. Thus sandarach is a mixture of three resins, copal of five, benzoin of three, guaiac of two, and gum lac and colophony also of several. He has shown likewise, that all these resinous bodies possess electro-negative properties, forming salts with oxides in definite proportions. These compounds are decomposed by the electric current, the resins being attracted to the positive, and the oxides to the negative wire. The alcoholic solutions of these bodies also redden litmus, so that there can be no doubt of their electro-negative character; though it would not only unnecessarily extend the meaning of the term *acid*, but also unnecessarily overburden the nomenclature, to apply the term to all these faintly negative substances, and to form classes of salts of their many obscure compounds. The labours of Unverdorben alone have already brought together such a mass of observations on this subject, that, as has been justly observed by Berzelius, were each of the resins to be examined with equal care, the detail would speedily occupy as much space as the whole of our present systems of chemistry."*

OF BASIC RESINS.

"Buchner and Herberger have advanced one step further in the investigation of resinous bodies. Unverdorben had found the *fifth* resin of copal to be *indifferent;*[*] these chemists describe some to be possessed of weak basic properties. Thus the resin extracted from jalap and from euphorbium they find to be each a compound of two; one of which is a weak acid, and the other a weak base; and they consider all the drastic gum-resins to be similar compounds. The subject, however, requires further investigation."[†]

---

* Johnson's Report on Chemistry for 1832, to the British Association for the Advancement of Science.

273. *Experimental Illustrations.*

A solution of gum precipitated by alcohol; a solution of resin by water.

* * *

SECTION IV.

OF GUM-RESINS.

This name is applied to a class of vegetable substances, which consist of a mixture of resin, gum, essential oil, and extractive matter. *Opium*, *aloes*, *ammoniac*, *assafetida*, *euphorbium*, *galbanum*, *gamboge*, *myrrh*, and *scammony* come under this head.

As the resin and essential oil require alcohol, the gum and extractive matter, water for solution, proof spirit is the best solvent of the gum-resins.

OF OPIUM.

[This complex substance contains the following proximate principles:—

1. Morphia, in the state of neutral sulphate, and supermeconate.
2. Paramorphia.
3. Pseudomorphia.
4. Codeia, in the state of supermeconate.
5. Narcotina.
6. Narceia.
7. Meconin.
8. Meconic acid, partly combined with bases.
9. Ulmin.

---

[*] An *indifferent* substance is one neither acid nor alkaline.

[†] Johnson's Report for 1832.

10. A peculiar resin.
11. A fatty oil.
12. Caoutchouc.
13. Gum.
14. Bassorin.
15. Lignin.
16. The sulphates of potash, lime, and magnesia.

Of these substances, *morphia*, *paramorphia*, *pseu phia*, *codeia*, *narcotina*, and *narceia* are ranked as v ble alkalies, all having the power of neutralizing *Meconin* is an indifferent or neuter substance, whic announced to exist in opium in 1832, by M. Couerb which is found to be identical with the *crystallizable ciple* of M. Dublanc, jun., discovered several years b The newly discovered principles, *paramorphia*, *pseud phia*, *narceia*, and *meconin*, exist in opium in very amount.]

◆

SECTION V.

OF NAPHTHA, PETROLEUM, BITUMEN, AMBER, A MINERAL COAL.

There is in nature a gradation of substances, appa arising from the wreck of a former world, from na which is highly volatile, to anthracite which is extr insusceptible of the aëriform state. Possibly the mond may be considered as terminating the series; has been suggested to result from the decompositi vegetable matter.

Bitumen, in its qualities, is intermediate betwee extremes; being separable, by distillation, into carbu hydrogen, a volatile oil, and carbon.

Petroleum is more fluid, lighter, and more inflam than bitumen.

The decomposition of the bituminous matter in *m coal* by ignition, yields carburetted hydrogen, as i gas-light process.

Naphtha is found pure in nature, and may likewi obtained by distillation from petroleum. Pure na is a volatile, inflammable, colourless, limpid liquid, a strong and disagreeable smell. A variety of this stance is distilled from coal tar, which condenses d the evolution of carburetted hydrogen from bituminous coal. Naphtha* is chiefly of use in preserving potassium. It consists of carbon and hydrogen; but the proportions in which its constituents are united have been variously represented by different chemists.

Amber is a singular fossil, which is supposed to owe its origin to vegetable matter. It is distinguished by burning with a peculiar odour, and yielding, when subjected to distillation, *succinic acid*, and a peculiar essential oil, called *oil of amber*, which much resembles naphtha in smell and other properties. The acid sublimes into the neck of the retort in crystals. Amber is insoluble both in water and alcohol. It resembles copal in appearance and properties.

◆

SECTION VI.

OF VEGETABLE ACIDS.

I propose, under this head, to treat particularly only of the more important vegetable acids.

OF ACETIC ACID.

Of all the vegetable acids, the acetic is most frequently found in nature, and is most easily produced by art. It exists in the sap of almost all plants, either free, or united with potash; likewise to a sensible extent in sweat, urine, and milk. During imperfect digestion, it is usually generated in the stomach. It is invariably a product of the destructive distillation of vegetable substances.

Preparation.—The distilled vinegar of pharmacy is a very dilute acetic acid. The acid may be obtained in a more concentrated form by distilling the acetate of copper; but in this case it is partially decomposed, producing a peculiar inflammable volatile liquid, called *pyro-acetic spirit.*

It may be procured also from any of its salts, by distillation with sulphuric acid.

In whichever of these modes it may be evolved, a second distillation is necessary to render it pure.

When obtained by sulphuric acid, it is liable to be con-

---

[*] See account of caoutchouchine, a fine artificial naphtha, page 438.

taminated with sulphurous acid, from which it may be purified, by adding a small quantity of black oxide of manganese, previously to the second distillation.

Properties.—The purest acetic acid which has been obtained, crystallizes at the temperature of about 55°. It is colourless, inflammable, very volatile, and has a very pungent odour and taste. Its specific gravity is 1.063, at 60°, and is not altered by the addition of an equal bulk of water. When thus diluted, its freezing point is lowered many degrees below that of water. The maximum of density 1.079 is produced by adding to the crystallizable acid, one-third of its weight of water.

Acetic acid probably consists of $C^4O^3H^3$.

OF PYROLIGNEOUS ACID.

In the process by which wood is converted into charcoal, acetic acid is evolved in combination with eupione, paraffine, kreosote, and a resinous matter called pyretine by Berzelius, forming the liquid known as pyroligneous acid.

When the process is performed with a suitable apparatus, this acid is collected. Pyroligneous acid may be considered as the matter of wood smoke in the liquid form; and when applied in this form to salted meat, is at least as efficacious as when employed as smoke in the usual way. The process of the smoke-house is less susceptible of precision, and is liable to produce an injurious rise of temperature.

From pyroligneous acid, pure acetic acid may be extricated by distillation with manganese or sulphuric acid, or with both; also by saturating it with lime, and decomposing the acetate of lime by sulphate of soda, separating the resulting acetate of soda by crystallization, and decomposing it by sulphuric acid, added in equivalent proportion. The sulphate of soda separating in crystals, the acetic acid may be obtained by decantation nearly pure. To procure it entirely free from the sulphate, it is distilled in an alembic, with a body of copper, and a head of tin or silver.

Acetates.—The acetates, it has been already mentioned, may all be made to yield acetic acid by heat, or the affusion of sulphuric acid. They are all soluble in hot water, and generally soluble in cold water. The acetate of mercury is nearly insoluble in cold water, and but slightly soluble in hot water.

Formerly, the acetate of potash was called *foliated earth of tartar;* the acetate of ammonia, *spirit of Mindererus.*

Any of the acetates may easily be formed, by saturating the acid with the proper base. Some of them may be obtained by double decomposition, as in the case in which sulphate of zinc and acetate of lead, yield acetate of zinc and sulphate of lead; or in that in which acetate of ammonia is procured by heating sal ammoniac with acetate of potash, when the ammoniacal acetate sublimes in crystals. This method is recommended by Thenard, as the best for preparing the acetate of ammonia for medicinal purposes.

274. *Experimental Illustrations.*

Distilled vinegar, and crystallizable acetic acid, exhibited; also pyroligneous acid.

OF CITRIC AND MALIC ACID.

The name of *citric acid* discloses its origin. It exists in the lime and lemon, in union with mucilage and malic acid. Its combination with mucilage is so intimate as to render it impossible to separate the acid, without first uniting it with some other matter. Alcohol is the most ready agent for this purpose, as it combines with the acid, and precipitates the mucilage. The alcoholic solution, thus obtained, does not yield crystals, even after evaporation, re-solution in water, and evaporating the water.

The most efficient mode of obtaining this acid pure, is to saturate the juice of lemons with chalk or whiting, and afterwards to decompose the citrate of lime, thus formed, by sulphuric acid duly diluted. The citric acid may be obtained in crystals from the supernatant liquid by evaporation.

Citric acid is crystallizable. Its taste is intensely acid when concentrated, but agreeably sour when dilute. It consists of $C^4H^2O^4$.

Malic acid derives its name from the apple; as in this fruit it predominates, as well as in gooseberries, currants, and other similar fruits. It may be had pure, by saturating lime with apple juice, and decomposing the malate of lime by sulphuric acid.

Professor Wm. Rogers, of William and Mary College, has ascertained that this acid abounds in different species of sumach in the state of bimalate of lime.

When heated to 380°, malic acid is resolved into two acids, one of which melts at 266°, the other at 392°.

Pelouze, who has recently investigated this subject, calls the former the *maleic*, the latter, the *paramaleic* acid. It would appear from the experiments of this chemist, that these acids are isomeric with each other.

It was formerly supposed that malic acid was one of the first products of the reaction of nitric acid with sugar, and that it was subsequently converted into oxalic acid by a continuance of the action. From experiments which have lately been made, it appears probable that the acid produced under these circumstances, differs from the malic in composition and properties.

Malic acid is composed, according to the recent analysis of Liebig, of $C^4H^2O^4$. It appears, therefore, to be isomeric with citric acid.

OF TARTARIC ACID.

Tartaric acid is found in many vegetables. It is named from *tartar*, an appellation given to a deposition from wine, which contains the bitartrate of potash. This bitartrate, when freed from impurities, is sold in the shops under the name of *cream of tartar*. When, to twenty-four parts of this salt, thirteen of carbonate of soda are added, sal Rochelle, a tartrate of potash and soda, is produced; and, in like manner, tartar emetic, by saturating the excess of tartaric acid with sesquioxide of antimony. Another pharmaceutical compound, called tartarized iron, is produced by saturating the excess of acid in cream of tartar with iron, which is taken up in the state of protoxide, but becomes, by exposure to the air, more or less sesquioxidized.

Tartaric acid is procured from cream of tartar in fine crystals, by saturating the excess of acid with chalk, and decomposing the precipitate by diluted sulphuric acid. The neutral tartrate of potash left, may be decomposed by quicklime, or by chloride of calcium, and the resulting tartrate of lime will yield the acid in the same way as the analogous tartrate obtained in the first instance by the addition of the chalk. Tartaric acid is extremely sour, and reddens litmus paper. Its symbolic formula is $C^4H^2O^5$.

A manufacturer of Thann, in Germany, in preparing tartaric acid from cream of tartar which had been deposited from the wine of that country, discovered an acid which differed from the tartaric acid, and which he supposed to be the oxalic. Gay-Lussac subsequently proved that, while possessed of peculiar qualities, its equivalent was the same as that of tartaric acid. By Berzelius it was afterwards shown to be isomeric with this last mentioned acid, and he has consequently named it *paratartaric acid.* The appellation of *racemic* has also been applied to it.

Paratartaric acid crystallizes in a different form from tartaric acid. It is likewise less soluble. The tartrates and paratartrates are isomeric.

When tartaric acid is exposed to heat, it swells up, melts, and is converted into a yellow transparent substance, which Braconnot supposes to be isomeric with tartaric acid.

OF TANNIC ACID, OR TANNIN.

There is a principle in vegetables which has the property of combining with the skins of animals, and converting them into leather. The process by which this change is effected is called *tanning;* and hence the matter producing it has been called *tannin.*

Although this appellation may be generally employed, yet as tannin forms combinations with various salifiable bases, and acts with sufficient energy to displace many of the acids, I concur with Berzelius in considering it as an acid, and consequently give it the appellation of *tannic acid.*

Tannic acid is found in a great number of vegetables, generally in their bark or roots, but not unfrequently in their leaves and seeds, and even in their flowers and fruits, before they have reached maturity. It is in fact the most frequent cause of astringency in vegetable products.

It may be procured, according to M. Pelouze, in a state of purity, by introducing powdered galls into a vessel, resembling a funnel, but contracted above into a neck like that of a bottle. The stem of this vessel should be plugged with cotton, and must be made to descend into a tincture bottle through the mouth. The galls are then to be covered with sulphuric ether of the officinal strength, and the mouth of the vessel covered, so as to prevent the evaporation of the ether. The liquid which descends into the bottle will be found to separate into two portions, of which the heaviest is a solution of tannic acid. From this solution the acid may be obtained in the solid form by evaporation.

Pure tannic acid is colourless, inodorous, and astringent to the taste. It is uncrystallizable. Its aqueous solution reddens litmus. It does not affect solutions of the salts of the protoxide of iron, but with those which contain the sesquioxide of this metal, it produces a precipitate of the tannate of iron. Pure tannic acid may in a few hours, be so completely removed from its solution by a piece of raw hide, that, if no gallic acid be present, the liquid will no longer affect a solution of the salts of the sesquioxide of iron; but if the last mentioned acid be present, a dark blue precipitate is formed with those salts.

The symbolic formula, representing the composition of tannic acid, is $C^{18}H^{8}O^{12}$.

Artificial Tannin.—A substance resembling tannic acid in many of its properties, and generally called *artificial tannin*, is formed during the action of nitric or sulphuric acid on a great variety of vegetable substances. One variety of this tannin is formed by the reaction of nitric acid with charcoal.

OF GALLIC ACID.

Gallic acid has been obtained in various modes. The following appears to me preferable. A concentrated decoction of galls, previously mixed with a little acetic acid to decompose the gallate of lime, is shaken with ether for one minute. The ether being decanted and evaporated, the gallic acid is isolated in small colourless prisms.

M. Pelouze infers, from the experiments which he has made, that gallic acid does not exist naturally in galls, but is produced by the action of the air on the tannic acid.

Gallic acid is white and crystalline. It reddens litmus, and has a feebly acid and astringent taste. In hot water it dissolves freely, although in cold water it is but slightly soluble. With solutions containing the sesquioxide of iron, this acid gives a dark blue precipitate of gallate of iron.

The colouring matter of ink is composed of gallate and tannate of iron. The composition of gallic acid, according to M. Pelouze, may be expressed by the following symbolic formula, $C^{7}H^{3}O^{5}$.

When a retort, containing gallic acid, is plunged in a bath of oil, heated to about 400°, an acid called *pyrogallic* sublimes; but if the oil be previously heated to ebullition, a new acid is produced, to which its discoverer, M. Pelouze, has given the name of *metagallic*. Pyrogallic acid was supposed, by Berzelius, to be a peculiarly pure gallic acid, but Braconnot has since shown that it differs from this acid both in properties and composition.

It appears that a small quantity of an acid, called the *ellagic*, is formed simultaneously with the gallic acid, when an infusion of galls is exposed to the air.

275. *Experimental Illustrations.*

Various metallic solutions precipitated by an infusion of galls.

OF SUCCINIC ACID.

When amber is exposed to heat in an alembic, succinic acid is sublimed in crystals, much contaminated by the essential oil of amber. By digestion in nitric acid, evaporation to dryness, washing in cold water, subsequent solution in boiling water, and finally by crystallization, the acid is obtained pure. When combined with any of the alkalies, it is useful in separating the sesquioxide of iron from the oxide of manganese.

Succinic acid has a sour taste, and reddens litmus paper. The symbolic formula for this acid is $C^{4}H^{2}O^{3}$.

OF BENZOIC ACID.

Benzoic acid is a concrete, volatile acid, existing in benzoin, or benjamin, from which its appellation is derived. It may be extricated from benzoin, either by sublimation, or by trituration with lime, digestion with water, and precipitation by chlorohydric acid.

Benzoic acid, when in union with ammonia, answers as well as succinic acid to separate iron from manganese.

The presence of benzoic acid characterizes what are now considered by chemists as *balsams*. There are three balsams formed by its union with particular resins—benzoin, already mentioned, styrax, and the balsam of Tolu.

Benzule.—In the oil of bitter almonds, and in benzoic acid, the existence of a common radical has been demonstrated by Liebig and Wohler, which is alleged to be represented by $C^{14}H^5O^2$; and to which the name of *benzule* has been given. With an atom of oxygen, benzule forms benzoic acid; with an atom of hydrogen, the oil of bitter almonds. Exposed to a current of chlorine, the oil abovementioned gives up an atom of hydrogen to the chlorine, thus generating chlorohydric acid and benzule, which, uniting with an atom of chlorine, forms a chloride. The chloride of benzule thus formed, subjected to water, is converted into benzoic and chlorohydric acids. When a hydrated metallic oxide is encountered by this chloride, one portion of the metal, uniting with the chlorine, gives up its oxygen to the benzule, which being thus converted into benzoic acid, unites with an undecomposed portion of the oxide, and forms a benzoate. Distilled with bicyanide of mercury, it gives a cyanide of benzule, and a chloride of mercury. Analogous results are obtained by the reaction of this substance with sulphides, iodides, bromides, &c. Benzule has not been isolated.

276. *Experimental Illustrations.*

Iron precipitated by succinic and benzoic acid. Crystals of benzoic acid, exhibited.

OF MECONIC ACID.

When a solution of acetate of lead is added to an infusion of opium, a precipitate is obtained, consisting of meconate of lead. From this the lead may be precipitated as a sulphide by means of sulphydric acid, and the liberated meconic acid may be obtained in solution by filtration. This acid exists in opium combined with morphia and codeia.

With solutions of the sesquioxide of iron, meconic acid produces an intense red colour; with protoxide of lead an insoluble precipitate. It is to this property that we owe the process, above described, for procuring this acid.

Meconic acid produces a taste, at first sour, and subsequently bitter, and reddens litmus paper. It is composed, according to Liebig, of $C^7H^2O^7$.

Of a Method of detecting the Presence of Opium.

The property which meconic acid has of precipitating with lead, and of producing a red colour with iron, may enable us to detect opium, when present in very small quantity in solution.

If ten drops of the tincture of opium, commonly called laudanum, be mingled with half a gallon of water, on adding a few drops of subacetate of lead, there will be a precipitation which, at the end of a few hours, will be perceptible in flocks. The descent of these flocks may be accelerated by detaching them gently from the sides of the recipient with a glass rod. The vessel should be conical, so as to concentrate them during their descent. After they are collected at the bottom of the vessel, about thirty drops of the red sulphate of iron, and an equivalent portion of sulphuric acid, should be introduced among them by means of a small glass tube. The presence of the meconic acid will be rendered evident by the redness which ensues.

When a red colour is produced by the means here described, it is probable that opium is present; as meconic acid is found only in that drug, and, having no active qualities, is not used separately from it in any pharmaceutical preparation.

It may be proper to mention that sulphocyanhydric acid produces, with the sesquioxide of iron, a colour resembling that produced by meconic acid.

277. *Experimental Illustrations.*

Into several vessels, each containing about half a gallon of water, and various quantities of laudanum, acetate of lead is first introduced. A precipitate of meconate of lead appears. At a subsequent period, when this precipitate has subsided, the presence of meconic acid is demonstrated by the addition of sulphuric acid and persulphate of iron.

OF KINIC ACID.

Kinic acid exists in Peruvian bark in union with quinia and cinchonia, the vegetable alkalies to which the active medicinal qualities of the bark are ascribed. It also exists in the bark in the state of kinate of lime.

As no useful application has been made of kinic acid, and no active qualities are ascribed to it, it would be useless to occupy attention with any details respecting the means by which it may be obtained.

OF VALERIANIC ACID.

This acid was first observed by Pentz and Grote. It exists ready formed in valerian. It presents the appearance of a limpid and colourless oil, having an extremely strong, and very acid and disgusting taste, and a smell resembling that of valerian. It is lighter than water. When heated on a platinum spoon, it burns with a bright flame, leaving no residue. It is capable of taking up twenty per cent. of water, without losing its oleaginous character. It dissolves in thirty times its weight of cold water, and in all proportions in alcohol. Its symbolic formula is $C^{10}H^9O^3$, as it exists in a dry state in certain salts; but in its free state as an oleaginous acid, deprived of water as completely as possible, it still retains one atom of that liquid.

OF CROTONIC ACID.

This acid was discovered by Pelletier and Caventou in the oil of the seeds of the ***Croton tiglium.*** It is a very volatile acid, possessing a powerful odour and an acrid taste. Taken into the stomach, it causes inflammation, and acts as a poison.

OF CEVADIC ACID.

This acid, discovered by Pelletier and Caventou, is a product of the saponification of the fatty matter of the *cevadilla.*

◆

SECTION VII.

OF VEGETABLE ALKALIES.

The discovery of this class of substances is of the highest importance to mankind. It has enabled the physician to avail himself of the active principles of some of the most powerful remedies, with a certainty which was before unattainable. The patient, in lieu of being nauseated and even injured by doses, of which the greater part, perhaps the whole, may be inert, if not injurious, has to swallow nothing which can be inefficacious, when judiciously prescribed.

According to Thenard, the vegetable alkalies are twenty in number, viz.—*morphia*, *paramorphia*, *pseudomorphia*, *codeia*, *narcotina*, *narceia*, *quinia*, *cinchonia*, *aricina*, *strychnia*, *brucia*, *delphia*, *veratria*, *sabadillia*, *emetia*, *solania*, *atropia*, *menispermia*, *melamia*, and *ammelia*. The following table indicates their sources, composition, and discoverers.

NAMES.	SOURCES.	COMPOSITION.*	DISCOVERERS.
Morphia,	Opium,	$H^{18}C^{34}O^{6}N$	Sertuerner.
Paramorphia,	do.	$H^{18}C^{34}O^{6}N$	Pelletier.
Pseudomorphia,	do.	$H^{18}C^{27}O^{14}N$	Pelletier.
Codeia,	do.	$H^{20}C^{31}O^{5}N$	Robiquet.
Narcotina,	do.	$H^{20}C^{40}O^{12}N$	Derosne.
Narceia,	do.	$H^{24}C^{32}O^{16}N$	Pelletier.
Cinchonia,	Peruvian bark,	$H^{12}C^{20}ON$	Pelletier and Caventou.
Quinia,	do.	$H^{12}C^{20}O^{2}N$	Pelletier and Caventou.
Aricina,	Bark of an unknown tree,	$H^{12}C^{20}O^{3}N$	Pelletier and Coriol.
Strychnia,	St. Ignatius's bean, nux vomica, &c.	$H^{16}C^{30}O^{3}N$	Pelletier and Caventou.
Brucia,	False Angustura bark,	$H^{18}C^{32}O^{6}N$	Pelletier and Caventou.
Delphia,	Stavesacre,	$H^{19}C^{27}O^{2}N$	Lassaigne and Feneulle.
Veratria,	White hellebore and meadow saffron,	$H^{22}C^{34}O^{6}N$	Pelletier and Caventou.
Sabadillia,	Cevadilla,	$H^{13}C^{20}O^{5}N$	Couerbe.
Emetia,	Ipecacuanha,	$H^{27}C^{37}O^{10}N$	Pelletier.
Solania,	Bittersweet and black nightshade,	$H^{68}C^{84}O^{28}N$	Desfosses.
Atropia,	Belladonna,	$H^{25}C^{68}O^{12}N$	Brandes.
Menispermia,	Cocculus Indicus,		Pelletier and Couerbe.
Melamia,	Artificial,	$H^{6}C^{6}N^{6}$	Liebig.
Ammelia,	Artificial,	$H^{5}C^{6}O^{2}N^{5}$	Liebig.

---

* The several formulæ indicate the quantity of each alkali in the anhydrous state, adequate to saturate one equivalent of an acid. B.

Natural State and Mode of Preparation of the Vegetable Alkalies.

The vegetable alkalies appear in almost every instance to exist in the vegetables to which they belong, in union with an acid. Thus, morphia is united with sulphuric and meconic acid, cinchonia and quinia with kinic acid, delphia with malic acid, and veratria with gallic acid. In some instances, the acids have not been specified; but the method requisite for the analysis, shows that they are present. The salt thus formed is entangled sometimes with resinous matter, sometimes with colouring matter, at others with fatty matter, and in a few instances with caoutchouc. In some cases several, in others, all of these impurities may be present. Very sparing solubility in water, and comparatively copious solubility in alcohol, are among the most striking attributes of these alkalies. The characteristics which I have mentioned, must of necessity prescribe the methods to be used, in the development of the principles to which they belong. Potash, soda, ammonia, lime, or magnesia, is used to displace the alkali from the acid naturally in union with it. The alkali thus displaced, from its insolubility in water, precipitates; sometimes with the precipitant, sometimes without it. Strong alcohol is employed to dissolve the alkali after precipitation. Previously to this step in the process, water, weak alcohol, or ether is occasionally used to remove resinous, colouring, or fatty matter; and in the case of morphia, when ammonia is added to separate and acetic acid to dissolve it, animal charcoal is employed to deprive it of colour. The decomposition of the native salts, in which these alkalies are found, is also effected, in some instances, by acetate of lead. The acetic acid unites with the alkali, and the oxide of lead with the acid which the alkali relinquishes. Sulphydric acid is afterwards used to remove any excess of the metal. Generally the alkalies are susceptible of crystallization, and of forming neutral crystallizable salts with the mineral and vegetable acids.

Chemical Characters of the Vegetable Alkalies.

They are all solid, white, inodorous, heavier than water, and either bitter or acrid. All of them render the syrup of violets green.

Veratria, *delphia*, and *emetia* can be obtained only in powder. The others are susceptible of crystallization.

They all yield ammonia by destructive distillation, which demonstrates that nitrogen is invariably one of their constituents.

They are all soluble in alcohol, and nearly, if not quite, insoluble in cold water.

When their salts are subjected to the Voltaic current, the alkali is always attracted to the negative pole.

Their affinity for acids is generally greater than that of the oxides of the metals proper, but is less than that of the alkalies and alkaline earths.

In solutions of their neutral salts, an infusion of galls causes a precipitate which alcohol dissolves.

Morphia and *brucia* produce, with nitric acid, a fine red colour; while the other alkalies, under the same circumstances, are either rendered yellow, or are scarcely altered.

In a solution of morphia, reddened by nitric acid, protochloride of tin causes a dull brown precipitate; while, in a solution of brucia similarly reddened, it causes a violet precipitate. Of the acetates of these alkalies, only that of morphia is crystallizable.

When the nitrate of *quinia* or of *cinchonia* is evaporated, —at a certain degree of concentration, globules of an oleaginous appearance are deposited, which congeal at a low temperature, assuming the aspect of wax. These globules, when covered by water, neither dissolve nor sustain any change of volume; but in a few days are converted into a group of shining prismatic crystals. By these characteristics, quinia and cinchonia may be distinguished from the other alkalies. They may be distinguished from each other, because quinia is fusible, uncrystallizable, and susceptible of a total decomposition by heat; while cinchonia is infusible, partially susceptible of volatilization, and crystallizable with facility. Besides, of their acetates, only that of quinia is crystallizable.

Strychnia is the only alkali which is both infusible and insusceptible of volatilization. When it contains brucia, it reddens with nitric acid, and yields a precipitate similar to that afforded by morphia. Hence, unless pure, it cannot be distinguished by these tests. The neutral nitrate of strychnia may be separated from that of brucia; since the former crystallizes, while the latter remains dissolved.

Emetia is pulverulent, very fusible, sensibly soluble in boiling water, insoluble in ether, and neither neutralizes acids, nor forms with them crystallizable salts.

Veratria may be detected by its extraordinary acridity, and by the violent sneezing which it excites. Besides, it is uncrystallizable, pulverulent, very fusible, soluble in ether, is rendered yellow by nitric acid, and resembles emetia in its habitudes with acids.

Delphia is distinguished from veratria by the difference of its physiological properties. Delphia is alleged to be inodorous, and is not said to excite sneezing. It produces a taste, which is at first bitter, but afterwards becomes acrid.

Constitution of the Vegetable Alkalies.

All the vegetable alkalies are constituted of hydrogen, carbon, oxygen, and nitrogen, except *melamia*, which is devoid of oxygen. Nitrogen enters into their composition in a quantity which varies from 4.30 to 9.02 in 100. In strychnia, which contains the most carbon, there are 78.22 parts in 100; while in emetia, which contains the least, this element exists in the ratio of 64.57 parts in 100. It follows, therefore, that it is the most abundant ingredient in this class of substances. In quinia, cinchonia, and strychnia, the nitrogen exceeds the oxygen in quantity; but the opposite is true, in the instances of veratria, brucia, emetia, and morphia.

"*Does the azote in vegetable alkalies constitute ammonia?* It has been found that the vegetable alkalies, so far as they have been examined with care, contain, as an essential constituent, a considerable quantity of nitrogen; and the question early suggested itself,—does the nitrogen in these salt bases exist in the form of ammonia? If so, it would be easy to understand why they exhibit alkaline properties. The experiments of Pelletier and Dumas appeared to supply a negative answer to the question, as well as the later ones of Liebig, who found that though brucia and strychnia are completely decomposed by nitric acid, yet ammonia is not one of the products. But there are other circumstances which are considerably in favour of the opposite opinion. Thus, in the six vegetable alkalies, morphia, narcotina, strychnia, brucia, quinia, and cinchonia, Liebig found that each atom contained one atom of nitrogen; and that thus the saturating power of each was in proportion to the amount of that element which it contained. The sulphates he found also to contain two atoms of water,* corresponding exactly to the quantity of water found by Mitscherlich to exist in the crystallizable salts of ammonia with the oxacids. These coincidences are extremely curious; and though they prove nothing, yet they show that we are not yet in a state to answer the question, definitively, whether the vegetable alkalies do really contain ammonia or not."†

Matteucci conceives that the following result which he has lately attained, is favourable to the opinion that alkalinity in the vegetable alkalies is due to the presence of ammonia. Sulphate of copper and pure morphia, finely pulverized and intimately mingled, were placed upon paper moistened with alcohol, and brought into contact with the copper plate terminating a galvanic pile of ten pairs. Under these circumstances, the evolution of ammonia is rendered evident by the production of a blue colour with the copper.

OF MORPHIA.

This alkali is one of the active principles of opium, in which it exists in union with sulphuric or meconic acid, and entangled with a great quantity of colouring matter. From the acids it may be separated by magnesia or ammonia. The colouring matter is removed by washing with cold water, and digestion with weak alcohol. After this, the morphia is dissolved in boiling hot alcohol, from which it crystallizes on cooling.

By Dr. Thomson, the morphia, after having been precipitated by ammonia in the first instance, is dissolved in acetic acid, and afterwards deprived of its colouring matter by animal charcoal.

Agreeably to the observations of Dr. Staples, of this city, this alkali may be precipitated from common laudanum, by a mixture of equal parts of aqua ammoniæ and alcohol; the alcohol being added to prevent the precipitation of matter insoluble in water. In about twelve hours the whole of the interior surface of the vessel will be studded with crystals intermingled with colouring matter, the crystals themselves being of the colour of brown sugar. By decanting the liquid, dissolving the crystals in acetic acid, and precipitating again by ammonia, the morphia may be obtained of a cream colour.

By adding chloride of calcium to a filtered aqueous infusion of opium, chlorohydrate of morphia and meconate of lime are formed by complex affinity. The latter, being insoluble, precipitates; the former remains in solution, and, by straining through a cloth, evaporation, re-solution, filtration, digestion with animal charcoal, a second filtration, evaporation, straining, and crystallization, may be isolated in a state of purity.

---

* "The sulphate of strychnia he has since found may be obtained in an anhydrous state."

† Johnson's Report, page 499.

Morphia is not soluble in cold, and but slightly soluble in boiling water. In alcohol, especially when boiling, it is very soluble. It is white and bitter, and crystallizes in slender, four-sided, obliquely truncated prisms. In small doses, it promotes sleep; in large doses, produces death.

OF PARAMORPHIA AND PSEUDOMORPHIA.

Paramorphia is an alkali lately discovered by Pelletier in minute proportion in opium. It is identical with morphia in composition, but quite distinct in its properties. It is, therefore, ***isomeric*** with morphia, and hence its name.

Paramorphia is white, scarcely soluble in water, of an acrid and styptic rather than a bitter taste, and very soluble in alcohol or ether, even when cold, and still more so when hot. It differs from morphia in not being reddened by nitric acid, in not forming crystallizable salts with acids, and in not striking a blue colour with the salts of iron. It differs also from morphia in its action on the system, producing ***tetanic*** symptoms in doses of a grain.

Pseudomorphia is the name given to another alkali discovered by the same distinguished chemist in opium, likewise in minute proportion. It resembles morphia in the characteristic properties of becoming red with nitric acid, and of striking a blue colour with the salts of iron, and yet differs from it in ***not being poisonous.*** It is not always present in opium, and the circumstances under which it is produced are not known.

OF CODEIA.

This vegetable alkali was discovered in 1832 by Robiquet. It exists in opium as a meconate. It is in the form of colourless crystals, which are sparingly soluble in water, soluble also in alcohol and ether, and insoluble in alkaline solutions. Its capacity of saturation is very nearly the same as that of morphia; but it may be distinguished from that alkali by the different form of its crystals, by its greater solubility in water, and by its insolubility in alkaline solutions. It has a decided action on the animal economy, producing, first, excitation, and afterwards depression.

OF NARCOTINA.

In order to obtain narcotina, opium may be shaved or otherwise comminuted, and digested with as much ether as will cover it, at a temperature near the boiling point of the ether, for three or four days. The ether being decanted and allowed to evaporate, the narcotina will appear in slender prismatic crystals. To remove all the narcotina, opium must be subjected to successive portions of ether.

OF NARCEIA.

This alkali was discovered in opium by Pelletier in 1832. It exists in white, silky, acicular crystals, inodorous, of a slightly bitter taste, sparingly soluble in water, more soluble in alcohol, and insoluble in ether. It is rendered blue by the dilute mineral acids, but does not, like morphia, become blue with the salts of iron, nor red with nitric acid.

OF CINCHONIA AND QUINIA.

These appellations have been employed to distinguish the alkalies found in Peruvian bark.

The following are the processes by which they were obtained by the discoverers, Pelletier and Caventou.

Two parts by weight of pale bark, ("Cinchona gris," or "Cinchona Condamenea,") were subjected, four times, to six parts of hot alcohol. The alcoholic tinctures were united and distilled to separate the alcohol; two parts of water being added towards the close of the distillation, to secure the residuum from injury by the fire. This residuum received on a filter, employed to separate it from the water, had a red colour, and a resinous appearance. In this state it was washed with water, weakly alkaline. After many days washing with alkaline water, this passed the filter, limpid and without colour. The matter on the filter was next washed with pure water, and afterwards appeared of a greenish-white colour. It was very fusible, soluble in alcohol, and gave crystals which were in the state of the cinchonia, as discovered by Dr. Gomez, of Lisbon, having some characteristics of a resinous substance. By solution in chlorohydric acid very much diluted, a quantity of green fatty matter was separated. This separation is imperfectly accomplished if the acid be strong.

The solution thus obtained was of a golden-yellow colour, and when evaporated it gave crystals, soluble in alcohol and water. Its taste was very bitter, and it was precipitated abundantly by alkaline solutions; and being slightly heated and mixed with magnesia, it yielded a precipitate. This, after washing with water, was dissolved in alcohol, producing a very bitter solution, whence crystals of cinchonia were obtained by evaporation. By subsequent solution in the same menstruum, and evaporation, cinchonia was obtained in very white, delicate, brilliant, prismatic, needle-shaped crystals.

Cinchonia, though nearly insoluble in water when cold, is soluble in it when boiling. A thousand parts, by weight, are requisite; and the solution becomes opake, or opalescent, on cooling.

It is very bitter, though, from its insolubility, this property is not immediately perceptible. Its sulphate and other soluble salts are excessively bitter; but the effect on the taste differs from that of a strong decoction of the bark, in not being associated with an astringency due to another principle.

Treating the yellow Peruvian bark, "quinquina jaune," (Cinchona cordifolia) by the process used in developing cinchonia, Messrs. Pelletier and Caventou were surprised to find a yellowish substance, apparently insusceptible of crystallization. This substance they were at first led to consider as cinchonia, disguised by foreign matter. It was, however, finally ascertained to be a vegetable alkali, analogous to cinchonia, but not identical with it.

The alkali, thus discovered, has been denominated quinia.

Quinia is so difficult to crystallize, that it was supposed to be uncrystallizable. It has since been obtained from its solution, in very highly concentrated alcohol, in crystalline needles, or fine crystalline tufts. When entirely deprived of water by drying, it appears a porous mass of a dirty white colour. It is almost insoluble in water, but readily dissolves in alcohol or ether. It is extremely bitter.

Sulphate of Quinia.—It appears to me that the most eligible process for obtaining sulphate of quinia, is as follows:—Boil a pound of the bruised bark with three fluidrachms of sulphuric acid in a gallon of water. Make a similar decoction of the same bark with half the quantity of acid, and again with a lesser quantity of acid, until all the soluble matter appears to be extracted. Add pulverized hydrate of lime, until the acid is saturated. By these means, sulphate of lime, mingled with quinia, will be precipitated. In the next place, the precipitate, being collected and dried, is to be boiled in alcohol, which will take up the quinia. The alcohol being removed by distillation, the quinia is to be saturated with sulphuric acid very much diluted with water, animal charcoal to be added, and the liquid concentrated by ebullition. Afterwards, by refrigeration, crystals of the sulphate will appear.

OF ARICINA.

This alkali was discovered in 1829 by Pelletier and Coriol, in a bark brought from *Arica*, on the Pacific Coast of South America, which was fraudulently mixed with the Calisaya bark. It is a white transparent crystalline substance, having a warm and acerb taste, which is long in developing itself. It dissolves in alcohol and ether, but is completely insoluble in water.

OF STRYCHNIA.

The poisonous principle of the Strychnos nux vomica, and Strychnos ignatia, proves to be an alkali, which is called strychnia. It may be developed by a process similar to that used for morphia. It was originally obtained by Pelletier and Caventou, by subjecting the bean of the strychnos ignatia, duly rasped, to nitric ether in a Papin's digester, to remove fatty matter; and subsequent exposure of the residue to alcohol, in which the strychnia, in union with an acid, dissolves. The alcohol having been evaporated, and the residuum dissolved in water, the addition of potash caused the alkali to precipitate. It was afterwards washed in cold water, and redissolved in alcohol, from which it crystallized by evaporation.

The colour of strychnia is white. Its taste is intolerably bitter, leaving a metallic impression in the mouth. It is nearly insoluble in water, or ether, but is very soluble in alcohol. It is a terrible poison, very small quantities producing tetanus to a fatal extent.

OF BRUCIA.

This alkali exists in the bark of the Brucia antidysenterica, or false angustura. The bark was first subjected to sulphuric ether, and afterwards to alcohol. The alcohol being evaporated, afforded a dry residuum, which was dissolved in water. The solution in water was saturated with oxalic acid, and evaporated to dryness. The residue was the oxalate of brucia, disguised by colouring matter, which was removed by alcohol. The oxalate of brucia was decomposed by lime or magnesia, either of which forms an insoluble salt with oxalic acid; while the brucia is soluble in 500 times its weight of boiling water, or in 850 parts of cold. Hence it was separated from the insoluble oxalate by water.

Brucia crystallizes in oblique prisms, with parallelograms for their bases. It is less bitter than strychnia, but its taste is more acrid and durable. It melts when heated a little above 212°, and congeals on cooling into a mass resembling wax. It neutralizes acids, affording a distinct class of salts. On animals, its effects are analogous to those of strychnia, but less violent.

OF DELPHIA.

It was in the seeds of the Delphinium staphisagria, or stavesacre, in which it exists as a malate, that this alkali was detected. A decoction of the seeds, which had been cleansed and reduced to a pulp, was filtered. The fluid, which passed the filter, was boiled with magnesia, which liberated the delphia. It was then separated from the magnesia by alcohol, and from this solvent by evaporation.

Delphia is white, pulverulent, and very soluble in alcohol and ether. It is inodorous, but its taste is extremely acrid and bitter. Water derives from it an acrid taste, though it does not dissolve any appreciable quantity. By combination with acids, it forms neutral salts, which are soluble in water, and very acrid and bitter.

OF VERATRIA.

This alkali is obtained from the seed of the Veratrum sabadilla; also from the roots of the Veratrum album (white hellebore), and Colchicum autumnale (meadow saffron).

The seeds, partially depurated by digestion with ether, yielded a coloured tincture with heated alcohol. This tincture deposited some waxy matter, on cooling, and by evaporation afforded a residuum, soluble in water, excepting a small portion of extraneous matter. The watery solution being slowly and partially evaporated, until an orange-coloured precipitate ceased to appear, acetate of lead was added to it. A copious yellow precipitate ensued, and the liquor, being separated from it by a filter, became almost colourless. This fluid was subjected to sulphydric acid, to precipitate any lead which it might contain. The solution then gave with magnesia, a precipitate, from which alcohol took up veratria. From the alcoholic solution, the veratria was afterwards isolated by evaporation.

Veratria is white, pulverulent, and inodorous, but, nevertheless, poisonous when inhaled, producing violent and dangerous sneezing. Its taste is not bitter, but excessively acrid. It is very soluble in alcohol and ether. Minute quantities, taken into the stomach, produce intolerable vomiting and sickness. Larger doses would certainly prove fatal.

OF SABADILLIA.

Sabadillia was discovered by Couerbe, as an alkali accompanying *veratria* in cevadilla, and in the roots of the Veratrum album (white hellebore) and Colchicum autumnale (meadow saffron). It is a white, crystallizable substance, insupportably acrid, fusible by heat, readily soluble in hot water, very soluble in alcohol, and wholly insoluble in ether.

OF EMETIA.

This alkali is obtained from ipecacuanha. The roots, well pulverized, are digested in ether. They are then subjected to alcohol, the resulting solution is evaporated, and the residuum dissolved in water and macerated upon magnesia, which causes the emetia to precipitate. This precipitate is washed with cold water to remove colouring matter, and afterwards subjected to alcohol, which takes up the emetia. The emetia again separated from its solvent by evaporation, being dissolved by diluted acid, and blanched by animal charcoal, may be precipitated pure by any of the alkaline oxides.

Thus obtained, emetia is white, pulverulent, and unalterable by the air, scarcely soluble in water, but very soluble in ether or alcohol. Its taste is slightly bitter. It restores the colour of litmus, when reddened by an acid; and is capable of forming crystallizable salts, like other alkalies. It appears to possess all the emetic properties of the root from which it is procured.

OF SOLANIA.

Solania is the name which has been given to an alkali, which exists in the black nightshade, (Solanum nigrum,) and in the bittersweet (Solanum dulcamara).

The filtrated juice of the berries of the nightshade is digested in ammonia; the precipitate which results is washed on the filter, and digested in boiling alcohol. After the evaporation of this fluid, solania is obtained in sufficient purity. It is a white, opake, pearly powder, which is inodorous, slightly bitter, and nauseous. Its acid solutions are more bitter. Its salts are uncrystallizable. In cold water it is insoluble, and in hot dissolves only to a small extent. It is very soluble in alcohol, but is not dissolved by ether. It restores the colour of litmus, reddened by an acid. It causes vomiting at first, afterwards sleep.

OF ATROPIA.

Atropia is procured from a decoction of the leaves of the Atropa belladonna, or deadly nightshade. Two pounds of the leaves were boiled in successive portions of water, which being united, and sulphuric acid added to the whole, the resulting liquid was filtered, and yielded a crystalline precipitate with potash. This precipitate, repeatedly dissolved in acids, and precipitated by alkalies, gave pure atropia. Thus obtained, it is snow-white, and quite tasteless. When recently precipitated, it is slightly soluble in water. After being dried, it is insoluble in water, ether, or oil of turpentine. In cold alcohol it is sparingly soluble; but copiously in the same menstruum when boiling hot.

Atropia forms compounds with acids, which cannot, however, be rendered so neutral as not to indicate acidity.

OF MENISPERMIA.

This alkali was discovered by Pelletier and Couerbe in the cocculus Indicus. It is a white, crystallized, opake, insipid, inodorous substance, insoluble in water, but soluble in alcohol and ether, especially when hot. It has no decided action on the animal economy.

OF MELAMIA AND AMMELIA.

These are two artificial alkalies, recently discovered by Liebig. They possess no importance.

SECTION VIII.

OF DOUBTFUL VEGETABLE ALKALIES.

Thenard enumerates the seven following substances, as principles of which the alkaline properties have not been fully proved; viz: *aconitin, daturin, hyoscyamin, corydalin, curarin, nicotin,* and *colchicin.*

Aconitin is obtained from the Aconitum napellus, or wolfsbane, of which it forms the active principle.

Daturin is the appellation given by Brandes to an alkaline principle, which, he alleges, he has extracted from the seeds of the Datura stramonium.

Hyoscyamin.—To a principle to which this appellation is given, the active qualities of the Hyoscyamus niger or henbane are attributed. It is alleged to be susceptible of crystallization, and capable of forming salts with acids.

Corydalin, "discovered by Dr. Wackenroder, is contained in the root of the fumitory, not the common fumitory (*Fumaria officinalis*), but *Fumaria cava,* and *Corydalis tuberosa* of Decandolle. It exists in the plant as a soluble malate, is precipitated from its aqueous solution by magnesia, and is purified by alcohol."[*]

Curarin was discovered by Boussingault and Roulin, in a matter employed by the savages of South America to poison arrows.

Nicotin.—Tobacco is alleged to owe its acridity and narcotic powers to a principle called nicotin, which exists in it combined with acetic acid.

Colchicin was obtained from the Colchicum autumnale by Geiger and Hesse. It is a white inodorous substance, of an acrid and very bitter taste, crystallizable in slender needles, and soluble both in water and alcohol.

The following substances, formerly supposed to be organic alkalies, are found to be *indifferent* or *neuter* principles; viz: *picrotoxin,* obtained from the cocculus Indicus; *pariglin* or *sarsaparillin,* from sarsaparilla;[†] *salicin,* from different species of Salix and Populus; and *cafein,* from coffee. *Meconin* is an indifferent or neuter substance, announced in 1832 as existing in opium by M. Couerbe. See analysis of opium, under the head of gum-resins, page 449.

SECTION IX.

OF THE VINOUS FERMENTATION.

When certain vegetable infusions, or mixtures of saccharine and farinaceous matter, or the juices of fruits, as those of the apple or grape, are kept at a temperature neither above 120°, nor below 50°, a chemical reaction ensues, during which carbon and oxygen unite, and escape in the form of carbonic acid gas; while the proportion of the hydrogen being increased in the residue, a new liquid is formed, in which hydrogen predominates. This liquid is *alcohol*, or *spirit of wine*, in which the intoxicating power of fermented liquors resides, and the process by which it is produced, is called the *vinous fermentation*.

---

[*] Turner's Chemistry, 5th English edition, page 845.

[†] See an account of the analytical researches which have been made on sarsaparilla, in the U. S. Dispensatory, 3d edition, page 577.

OF YEAST OR FERMENT.

The vinous fermentation is wonderfully and mysteriously promoted by the presence of a ferment. This is a peculiar species of matter, usually called yeast, which is extricated or formed during fermentation, and which, from its viscidity, so envelops the carbonic acid, generated at the same time, as to be elevated by it to the surface of the liquid. The part which yeast performs as an exciting cause of fermentation, seems to be somewhat analogous to that of a virus, in inducing disease similar to that from which it originates.

It has always appeared to me possible that the vinous and acetous fermentations were severally due to appropriate animalcules, of which yeast might be the eggs; or in the case of the acetous fermentation, that the mother of vinegar might be similarly constituted. It is remarkable that the temperature requisite for fermentation, has nearly the same limits as that requisite for life.

The proportion of yeast required to induce fermentation is very small, not being more than one part in one thousand when judiciously managed.

The juice of the apple, and that of the grape, ferment spontaneously, in consequence of the presence of some matter, naturally existing in the fruit, which operates like yeast. A pure solution of sugar does not spontaneously undergo the vinous fermentation.

Whatever may be the nature of the septic principle in vegetables, a temporary exposure to the air is indispensable to give it activity. Vegetable juices may be prevented from entering into fermentation, by heating them to the boiling point, and sealing them up in bottles, so as to exclude the air completely; but, after fermentation has been induced, it cannot be arrested by excluding the air.

OF ALCOHOL.

By the distillation of fermented liquors, the alcohol in them is separated; as it boils at a lower temperature than water. It still contains, however, more or less of this liquid; and though depurated from it to a considerable degree by repeated distillations, the chemical affinity of pearlash, or some other substance attractive of moisture, is requisite to produce the highest possible degree of purity, at which the specific gravity of alcohol is to that of water, nearly as 800 to 1000, at 60° F.

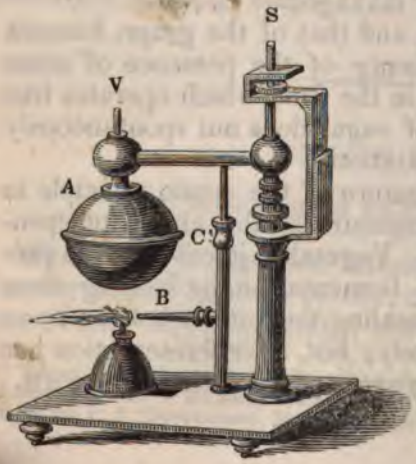
Properties.—The union between alcohol and water is so energetic, as to cause a rise of temperature and a diminution of volume, when they are mixed.

Alcohol, by combustion, yields only water and carbonic acid. It is more expansible than water, and boils at 176°. Its capacity for heat, whether in the liquid or aëriform state, is much less than that of water. It is a powerful solvent, and a highly useful agent in pharmacy, and in the delicate analysis of vegetable and animal matter. It is alleged that it has been frozen by a cold of —90° by Bussy.

I have ascertained that the addition of one-seventh of oil of turpentine will render the flame of alcohol so luminous, as to be a competent substitute for a candle flame.

When alcohol is passed through a red-hot porcelain or copper tube, it is decomposed into equal volumes of water and olefiant gas. Yet it will appear from the next section, that carbon and hydrogen are now conceived to exist in alcohol not as olefiant gas, but as etherine.

278. *Alcohol Blowpipe.*



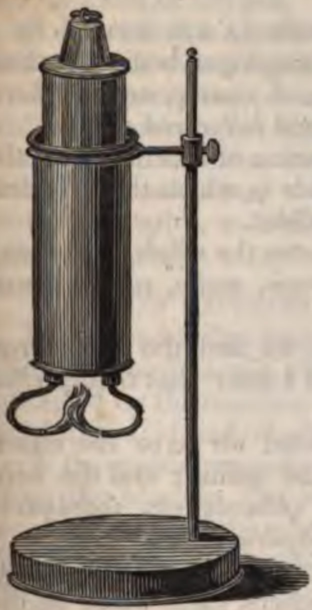
A flame resembling that of the enameller's lamp, may be produced by a small boiler, A (see fig.) containing alcohol, in which alcoholic vapour is generated, as steam is by the boiler of a steam engine.

The vapour thus generated, is substituted for air in the blast of the blowpipe, being directed upon the flame of a lamp in the same way, by means of a pipe proceeding from the boiler, and terminating in a beak with a capillary orifice, B. The boiler is furnished with a safety valve, V.

It may be objected to flame thus excited, that, as the oxygen is not so copiously supplied as when a stream of air is used, the oxide of lead in flint glass tubes is reduced by it, and the glass consequently blackened.

The apparatus, here represented, is furnished with an adjusting screw, S, by which the height of the boiler is regulated; while the communication is preserved between it and the beak by means of a tube sliding through a stuffing box, C, which surmounts a larger tube to which the beak is soldered.

279. *New Modification of the Blowpipe by Alcohol.*



This figure represents an improved blowpipe by alcohol. In the ordinary construction of the blowpipe by alcohol, the inflammation is kept up by passing a jet of alcoholic steam through the flame of a lamp, supported as is usual by a wick. The inflammation of the jet cannot be sustained without the heat of the lamp flame; since the combustion does not proceed with sufficient rapidity, to prevent the inflamed portion from being carried too far from the orifice of the pipe, and from being so much cooled by admixture of air, as to be extinguished. By using two jets of vapour in opposition to each other, I find the inflammation may be sustained without a lamp. If one part of oil of turpentine with seven of alcohol be used, the flame becomes as luminous as a gas light.

In order to equalize and regulate the efflux, I have contrived a boiler like a gasometer. It consists of two concentric cylinders, open at top, leaving an interstice of about a quarter of an inch between them; and a third cylinder, open at bottom, which slides up and down in the interstice. The interstice being filled with boiling water, and alcohol introduced into the innermost cylinder, it soon boils and escapes by the pipes. These pass through stuffing boxes in the bottom of the cylinder. Hence their orifices, and of course the flame, may be made to approach to, or recede from, the boiler. It must be obvious that the introduction of the alcohol requires the temporary removal of the intermediate cylinder.

◆

SECTION X.

OF ETHERS.

By the reaction between alcohol and various acids and other active bodies, a variety of volatile, inflammable liquids are produced. These liquids are called generically ethers, and are individually distinguished by associating with the generic appellation, that of the agent by means of which they are generated, and of which, in a majority of instances, they partially consist.

The generic appellation *ether* has likewise been extended to some analogous liquids, formed by the reaction of the halogen bodies with alcohol. A simple conception of the various ethers is obtained, by contemplating them as having a common base, *etherine*, of which E is the symbol, and 4CH the formula. Consistently with this view of their composition, the following classification may be adopted:—

Amphigen ethers, embracing such as are formed by a union of etherine with any of the amphigen bodies, or their acid compounds, and comprising, of course, *oxacid ethers*, *sulphacid ethers*, *selenacid ethers*, and *telluracid ethers*.

Halogen ethers, formed by the union of etherine with the halogen bodies, or with the acids in which these bodies act as the electro-negative ingredient.

The oxacid ethers would comprise the *sulphuric*, *nitric*,[*] *oxalic*, *tartaric*, *citric*, *acetic*, *formic*, *malic*, *succinic*, and *cyanic ethers*, &c.

Sulphacid ethers.—In this class we find the *sulphydrate of etherine*, called *mercaptan*, and I infer that *thialic ether* belongs to it.

Halogen ethers.—Under this head we have the ethers formed with chlorine, bromine, and iodine; and the *halohydric ethers*,[†] embracing the *chlorohydric*, *iodohydric*, *bromohydric*, *cyanhydric*, and *fluohydric ethers*.

Agreeably to recent observations which show that *mytheline* acts as a base in certain ethers, there would be different orders, according to the base present; as for instance, *Order 1st, Etherine Ethers; Order 2d, Mytheline Ethers*.

I once obtained a liquid which seemed to have the same relation to sassafras oil or sassafrine, that alcohol has to etherine, or pyroxylic spirit to mytheline. It is, therefore, possible there may be other orders of ethers.

The ether, commonly although erroneously called sulphuric ether, consists of an atom of water acting as an acid, and an atom of etherine. The ethers formed with the acids which require water for their existence, and which might therefore be called *hydrated acids*, consist of an atom of one of those acids, combined both with the requisite atom of water, and with an atom of etherine.

---

[*] Nitric ether contains the acid of nitrogen which consists of three atoms of oxygen to one of nitrogen. As this compound is called *nitrous acid* by Berzelius and others, while in Great Britain it bears the name of *hyponitrous acid*, I adhere, for the present, to the name of nitric ether, heretofore generally used.

[†] By halohydric ethers I mean such as consist of etherine and a halohydric acid, or an acid composed of hydrogen in union with a halogen body.

By the union of the halogen bodies, or halohydric acids with etherine, anhydrous ethers are formed. The halohydric ethers obviously differ from hydric ether, only in the substitution of an atom of one of the halogen bodies for an atom of oxygen.

Some chemists attach to the etherine, the atom of water entering into the composition of the hydrated acid ethers; as if they were compounds of their respective acids in the anhydrous state, and hydric ether. As some acids, especially organic acids, cannot exist isolated from water, I deem it more correct to consider the water as associated with them *after*, as well as *before* their union with etherine.

OF HYDRATED ORGANIC ACID ETHERS.

Ethers under this designation, as for instance the *acetic, formic, tartaric, oxalic, citric, succinic, and malic ethers*, are obtained by the reaction of a salt containing the acid, with sulphuric acid and alcohol. The organic acid, together with the water requisite to its existence, being displaced from the base by the stronger affinity of the sulphuric acid, unites with the etherine contained in the alcohol, and forms a peculiar ethereal liquid, which is distinguished by the name of the acid which enters into its composition.

The limits of this work do not allow of my treating of these ethers in detail.

OF HYDRIC ETHER, COMMONLY CALLED SULPHURIC ETHER.

When equal weights of alcohol and sulphuric acid are mixed and distilled, a liquid, known by the name of sulphuric ether, is produced. If the distillation endure sufficiently, fumes of sulphurous acid, and a yellow sulphurous ethereal liquid, together with water come over. Finally the residue rises in a foam, so as to render it necessary to terminate the process.

To remove the sulphurous acid, the product of the distillation should be refrigerated by ice, and agitated with liquid ammonia in a well closed bottle, surrounded by ice and salt. If refrigeration were not employed, the sulphurous acid would, in consequence of the generated heat, carry off much of the ether.

The resulting ethereal solution, being separated by a funnel from the ammonia, should in the next place be subjected to distillation by means of a water bath, which is at first heated to 120° to separate the ether, and afterwards raised to a boiling heat to obtain the compound of alcohol, ether, and oil of wine, called *Hoffmann's Anodyne liquor*.

Obtained as abovementioned, ether is sufficiently pure for medicinal purposes, and generally for those of the laboratory, but is not free from water and alcohol. In order to depurate it of these liquids, it must be mixed with anhydrous chloride of calcium, and distilled with a heat not higher than 120°.

Properties.—Hydric ether is very volatile and light, being when pure, in weight compared with water, as 700 to 1000. The cold, produced by the evaporation of this liquid in the air, and by its ebullition in vacuo, was adduced among the phenomena of caloric, page 92 and 117. Under the pressure of the atmosphere it boils at 98°, and in vacuo, below the freezing point of water. It combines with water to a limited extent, but unites with alcohol in any proportion. It freezes at —46°.

Hydric ether has peculiar and highly useful properties as a solvent.

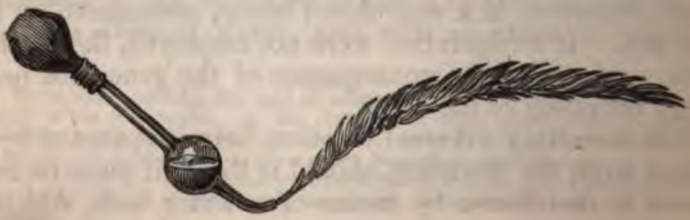
280. *Experimental Illustrations.*

Equal parts by weight of sulphuric acid and alcohol, being mingled in a retort and distilled, hydric ether is obtained and exhibited.

281. *Surprising Inflammability of Hydric Ether illustrated.*

The inflammability of hydric ether may be illustrated by applying the flame of a taper to a jet of it, while passing through the air, as represented in the following figure. Under these circumstances, the ether is converted into a continuous arch of flame.

The jet may be produced by compressing the bag with the hand, or by heating the bulb containing the ether, so that the pressure of the vapour, generated by ebullition, may propel the liquid in a stream from the capillary orifice. If the latter method be adopted, the bag may be dispensed with.



OF SULPHATE OF ETHERINE, OR OIL OF WINE, THE ONLY TRUE SULPHURIC ETHER.

It has been mentioned that, when the residual liquor from which hydric ether has been distilled by a heat not exceeding 120°, is exposed to the temperature of boiling water, a liquid is obtained, which has the virtues of Hoffmann's anodyne. This preparation should produce a milky appearance with water, in consequence of the presence of sulphate of etherine, which is insoluble in that liquid. This ethereal sulphate is formed towards the close of the ordinary process for making hydric ether, and may be obtained more directly by mingling, and subjecting to distillation, equal measures of alcohol and sulphuric acid.

Consistently with the knowledge which has been obtained by recent investigations, especially those of Hennel, alcohol consists of two volumes of the vapour of water, united to one volume of the vapour of etherine, which consists of four volumes of each of its ingredients, carbon and hydrogen, and acts as a base. On the access of sulphuric acid under favourable circumstances, it forms a hydrous bisulphate of etherine, or sulphovinic acid. The energy of the affinity exercised by the acid to the elements of the alcohol, is shown by the elevation of the boiling point of the mixture; which I have ascertained to be at least 250°.

When the proportion of alcohol is in bulk twice that of the acid, the resulting bisulphate of etherine, on being subjected to heat, gives up a portion of its etherine and water, so that the monohydrate of etherine, or hydric ether distils. But when the proportion of acid is sufficient to hold the water and etherine, till the temperature reaches a certain elevation, a reaction ensues between the hydrogen of part of the etherine, and the oxygen of the acid, by which carbon is separated and sulphurous acid evolved. This acid, leaving the carbon in the retort, comes over in union with the hydric ether, and at the same time with a small proportion of sulphate of etherine. Of the liquid which comes over, if sufficient refrigeration be employed, full one-half by weight consists of sulphurous acid, which may be removed by agitation with ammonia in an ice bath. When by these means the yellow colour and suffocating odour arising from the simultaneous presence of sulphurous acid and sulphate of etherine are removed, the residual ether, floating on the ammoniacal solution, may be separated by a funnel, and subjected to evaporation by means of a water bath raised gradually to boiling. The sulphate of etherine will remain in the retort, mingled with an aqueous solution of sulphuric or sulphovinic acid. Being separated carefully from this aqueous solution, washed with a little water, and extricated from the washings, it may be depurated from uncombined moisture, either by exposure in vacuo over sulphuric acid, or by a heat above 212°.

Thus procured, sulphate of etherine has an unctuous consistency, from which it derives its usual name of *oil of wine*. It is transparent, nearly colourless, and highly fragrant; while its taste is pungent, resembling that of the oil of peppermint.

Berzelius describes two oils of wine; one as the *heavy oil*, the other as the *light oil*. The former he represents as aromatic, and highly flavoured; while the latter is described as smelling unpleasantly. According to Thenard, by digesting the heavy oil with water, a light aromatic oil is obtained; from which, if kept in ice for about 24 hours, a crystalline substance separates, which he designates as the *concrete oil of wine*. These compounds resemble those which Hennel described as resulting from the digestion of the heavy oil with an aqueous solution of potash. They were by him viewed as the base of the oil of wine freed from sulphuric acid, which base he called ***hydrocarbon.*** This appellation has been supplanted by that of ***etherine.***

One of the products, obtained by Faraday from the liquid deposited by carburetted hydrogen, condensed for the purpose of gas-lighting, is considered as pure etherine by Thenard and Turner. I have obtained several liquids having the characteristic flavour of oil of wine, varying somewhat in their gravity, and containing various proportions of sulphuric acid. From fourteen grains of one specimen distilled from ammonia, and which still retained the odour and flavour of oil of wine, I only could procure, by adding nitrate of baryta, two grains of the sulphate of that earth. Fourteen grains of another specimen yielded, before distillation, its own weight of the same sulphate; after distillation, only nine grains. It would seem either that the sulphuric acid does not exist in the heavy oil in a constant proportion, or that the sulphate of etherine described by Hennel is liable to be mingled with etherine devoid of sulphuric acid. It is so difficult to remove this acid entirely, that I was myself induced, in common with Thenard, Boullay, Dumas, and many other chemists, to infer its absence from pure oil of wine. Latterly I have distilled oil of wine from potassium, and yet found the resulting liquid to hold sulphuric acid as an ingredient.

OF SULPHUROUS ETHER.

Between sulphurous acid and hydric ether, which are the ingredients of sulphurous ether, an affinity exists resembling that between alcohol and water. Sulphurous acid boils at —12°, hydric ether at 98°. The difference being 110°, of course were not the affinity more energetic between these fluids, than between alcohol and water, of which the boiling points differ only by 36°, they could not remain united at ordinary temperatures. The boiling point of sulphurous ether is lowered in proportion as the ratio of the acid to the hydric ether is increased. When it contains sulphate of etherine, the temperature necessary to the ebullition of the aggregate, is inversely as the quantity of the sulphurous acid, and directly as that of the sulphate of etherine, to the quantity of the other ingredient. Hence, although I have obtained sulphurous ether which boiled at 28°, it is difficult with the heat of a boiling water bath, to separate the last portion of this ether from the sulphate of etherine; and then a part of the latter distils with it.

I kept twenty-six measures of the compound of sulphurous ether and sulphate of etherine, which I call *ethereal sulphurous sulphate of etherine*, in a glass measure over water for three weeks, without the slightest perceptible diminution of the quantity of the former. By means of a stopple secured by screws, about an ounce measure of the volatile sulphurous ether was kept in contact with water for more than six weeks without apparent alteration. Even when in contact with ammonia, the transfer of the acid from the ether to the alkali takes place slowly, unless agitation be employed.

OF HOFFMANN'S ANODYNE.

It has been stated that when, in the process of etherification above described, the materials have a certain ratio to each other, and are exposed to a temperature sufficiently elevated, a liquid distils which consists of sulphate of etherine, sulphurous acid, and hydric ether. If to this compound,

hich I have already designated as the ethereal sulphurous sulphate of
therine, while refrigerated by ice water, liquid ammonia, also refrigerated,
e gradually added, and the mixture agitated, the ethereal solution loses
alf its bulk and weight. The residual liquid which floats upon the am-
oniacal solution, being separated by a funnel, forms, by dilution with
wenty-four times its bulk of alcohol, the anodyne liquor which I have
een accustomed to prepare.

Statements and Suggestions respecting Hoffmann's Anodyne.

It appears to me possible that the efficacy of the anodyne liquor above
escribed, may be owing in some degree to the greater stability imparted
the ether by its union with oil of wine. It is, however, worthy of
nquiry whether the oil of wine, prepared without the ether, would have
ny peculiar efficacy. I have the authority of my late colleagues Dr.
hysick and Dr. Dewees for stating, that the anodyne liquor prepared
greeably to my process, "is highly useful in some disturbed states of the
ystem, in tranquilizing, and in disposing to sleep."

It has been mentioned that alcohol containing sulphate of etherine, pro-
luces a milky appearance with water, in consequence of the precipitation
of the sulphate of etherine, which is insoluble in water. This Dr. Physick
had long remarked as an essential character of the genuine Hoffmann's
anodyne liquor. At one period, there was scarcely any to be found in the
shops of this city, which possessed this characteristic; but the defect,
having been pointed out, has been corrected by many of our druggists.

In the old way of making hydric ether, a certain quantity of Hoffmann's
nodyne had always been obtained towards the close of the process; but
new process was introduced, agreeably to which an additional quantity
f alcohol being added, before the materials could reach the state of con-
entration requisite for producing sulphate of etherine, the anodyne liquor
eased to be a concomitant product of the ether. Hence a mixture of ether
nd alcohol was used as a substitute for it both in this country and in
rance.

Agreeably to the formula for Hoffmann's anodyne, given in the London
harmacopœia, two "fluidrachms" of oil of wine are to be added to a
nt of "spirit of sulphuric ether," consisting of two parts of alcohol and
ne of hydric ether. This process is preferable as respects precision, but
liable to the objection that the oil is more difficult to procure than the solu-
on of it in alcohol, which may always be generated towards the close of
e old process of etherification. I question whether the presence of ether
advantageous in all cases.

I regret that no adequate efforts have been made to ascertain the medi-
nal virtues of oil of wine, and how far the admixture of hydric ether
ay tend to improve or impair its efficacy.

282. *Experimental Illustrations.*

A mixture of two parts of alcohol with one of sulphuric
cid, by measure, being mixed and distilled, hydric ether
obtained: also, ethereal sulphurous sulphate of etherine.
xhibition of the process for Hoffmann's anodyne above

described: also of the milky appearance arising from its admixture with water.

OF CHLOROHYDRIC OR MURIATIC ETHER.

Chlorohydric ether may be obtained by distilling water with concentrated chlorohydric acid. The distillation is performed by means of a glass retort, communicating by a tube with some water at the temperature of about 90° F., in a bottle with three orifices. Through one orifice, the tube proceeding from the retort enters, and is luted air-tight; into another orifice, a tube of safety is inserted; from the third orifice proceeds another tube, bent twice at right angles, so as to reach the bottom of a long narrow phial surrounded with a freezing mixture, the orifice being nearly, but not quite closed. The water in the intermediate vessel detains any alcohol or acid evolved with the ether, which, in consequence of its greater volatility, reaches and is condensed in the phial. See page 205.

Chlorohydric ether is very volatile, being a permanently aëriform fluid above the temperature of 70°. When poured upon the hand it boils, and produces a sensation of cold. In smell it resembles sulphuric ether. It has a sweet taste. Its specific gravity is to that of water, as 874 to 1000. When passed through an ignited tube, it is resolved into equal volumes of olefiant and chlorohydric acid gas. It consists of one volume of etherine, and two volumes of acid.

OF IODOHYDRIC AND BROMOHYDRIC ETHER.

Iodohydric ether was generated by Gay-Lussac, by distilling iodohydric acid with alcohol. It is much heavier than water, being of a specific gravity of 1.9206 at 72° F. It boils at 148°. Its smell is analogous to that of the other ethers. By keeping it disengages iodine, and acquires a rose-red colour.

With bromohydric acid, an ether may be formed analogous to those produced with iodohydric and chlorohydric acid.

OF THE ETHEREAL COMPOUNDS OF ETHERINE WITH HALOGEN BODIES.

Under the name of bichlorine ether, the compound formed by the union of olefiant gas and chlorine is mentioned at page 291. It appears that there are other compounds of chlorine with carbon and hydrogen, of which an account is subjoined. In what form the carbohydrogen exists in them is still doubtful. See *carbohydrogen*, page 286.

Of these compounds, one has been known heretofore as chloric or "heavy muriatic ether," being obtained by the reaction of chlorine with alcohol. It may be called *protochlorine ether*.

This ether is a liquid of an oleaginous consistency, an agreeable odour, and a sharp taste. It consists of one atom of etherine, and one of chlorine.

Bichlorine ether, generally called chloric ether, is alluded to at page 291, as formed by the reaction of chlorine with olefiant gas. It is a colourless, oily looking liquid, with a peculiar odour, and a sweet aromatic taste.

Perchlorine ether was obtained by distilling alcohol from chloride of lime, by Mr. Guthrie, of Sacket's Harbour, New York, who, however, supposed it to be identical with the ether last described. Not long afterwards, without any knowledge of the experiments of Guthrie, it was procured by Soubeiran in France, and alleged to be a compound of one atom of etherine, and four of chlorine. Dumas, however, states its composition to be, one atom of bicarburet of hydrogen, and three of chlorine.

Perchlorine ether is a volatile liquid, of an agreeable odour, and a sweetish aromatic taste. Both this and bichlorine ether have been advantageously employed in medicine.

Bromine and iodine also combine with carbohydrogen, probably in the state of etherine. The resulting compounds have qualities in some respects analogous to the chlorine ethers, but that formed by iodine is a pulverulent solid. Both bromine and iodine ether are produced by the reaction of these halogen elements with olefiant gas. That formed with iodine is generated by the aid of the solar rays.

OF NITRIC ETHER.*

This ether may be obtained in a diluted state, by distilling alcohol with diluted nitric acid, or with nitre and sulphuric acid. When sulphuric acid is used, the product is liable to consist in part of sulphuric ether.

Thenard informs us that to obtain pure nitric ether, equal parts of alcohol, and of the nitric acid of commerce, may be mixed and distilled with great caution, the product being passed into a series of Woulfe's bottles, the first empty, the others half filled with brine, and surrounded by a freezing mixture. As soon as the reaction commences, it increases rapidly, so that it is necessary to check it by cooling the retort.

I subjoin an engraving and description of an apparatus which I have contrived for generating nitric ether.

I am of opinion that it would be advantageous, if the prescriptions of our physicians were made with reference to ingredients of a high degree of purity. The physician should know how much real nitric or sulphuric ether is contained in the diluted article which he directs his patient to use. Hence pure nitric or sulphuric ether should be prescribed, adding as much alcohol or water as he may deem necessary. Agreeably to the present practice, it is in the power of manufacturing chemists to impoverish ethereal preparations with little danger of detection.

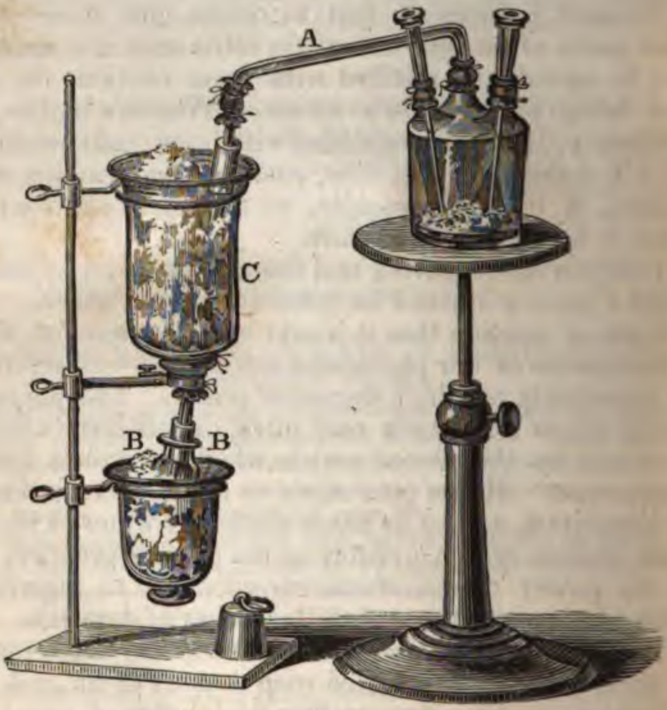
Pursuant to the London Pharmacopœia, three ounces of nitric acid, by distillation with a quart of alcohol, are allowed to produce twenty-four fluidounces of sweet spirit of nitre. According to Thenard, the quantity of ether, when the materials are in the ratio of equality, amounts to two-thirds of the weight of the acid. Hence it is probable that the quantity of ether in the twenty-four fluidounces of sweet spirit of nitre, obtained as abovementioned, is not more than two ounces.

---

* The proper appellation of this ether being unsettled, I adhere to that generally used.

I infer that sweet spirit of nitre of a more uniform strength, would be obtained by the addition of alcohol to pure nitric ether, to an extent no more than adequate to render it soluble in water; and then adding water to the alcoholic solution, until the ether should form only a twelfth of the aggregate. In a preparation thus made, the properties of the ether would not be unnecessarily associated with those of alcohol, as in the usual officinal preparation.

283. *Process for Spirit of Nitric Ether, or Sweet Spirit of Nitre, by Means of an approved Apparatus.**



The reaction of nitric acid with alcohol is so difficult to regulate, in the ordinary mode of making nitric ether, in which the whole of the materials are mingled at the outset of the process, that I was induced, about twelve or fifteen years ago, to introduce an apparatus, in which they were gradually added together within a glass bottle, by means of glass funnels with glass cocks.

---

* See Transactions of the American Philosophical Society, vol. 5, new series.

Subsequently I adopted the more simple apparatus represented in the preceding figure.

Providing a bottle with three tubulures, let one tubulure communicate, by means of a recurved tube A, with another tube passing perpendicularly through an open-necked inverted receiver C, and entering a bottle surrounded with ice and salt, occupying a suitable vessel B B. The cavity of the receiver should likewise be occupied by a freezing mixture.

Into each of the remaining tubulures let a glass tube be introduced, ground or luted to fit air-tight, and tapering so as to terminate in a capillary orifice near the bottom of the bottle.

Through one of the tubes introduce as much alcohol as will cover the bottom of the bottle; and then, by means of the other tube, introduce as much strong nitric acid as will cause an effervescence. Should the effervescence threaten to become explosive, the reaction may be checked by the further addition of alcohol; and when the reaction appears to decline too much, it may be re-excited by an additional quantity of acid. By these means, without applying heat, a quantity of nitric ether will soon be condensed in the refrigerated bottle. To convert this ether into a liquid, fully equal to the officinal sweet spirit of nitre, let it be mingled with seven parts of alcohol, and four of water.

The colder the freezing mixture, the greater will be the product; yet more or less may be obtained by refrigeration in cold water.

It may be proper to mention that, at the bottom of the phial, an aqueous acid liquor is deposited, upon which the ether swims, and from which it should be carefully separated.

OF THIALIC ETHER, AND OF MERCAPTAN AND MERCAPTUM.

By the reaction of the sulphovinates with the bisulphide or the sulphydrate of barium, Zeisse has obtained two volatile liquids, one of which he calls *thialic ether*, the other *mercaptan* (from corpus mercurium captans) on account of its singularly energetic reaction with the bioxide and bichloride of mercury. Mercaptan appears to consist of one atom of etherine, and two atoms of sulphydric acid. In reacting with the bioxide or bichloride of mercury, yielding an atom of hydrogen, and receiving an atom of metal, it is converted into a compound, called by Zeisse a *mercaptide*, and which is considered by him as consisting of *mercaptum*, a principle which has never been isolated, and the metal. Mercaptum is capable of combining with other metals, gold and platinum for instance. The resulting combinations are called by their discoverer mercaptides.

Mercaptan consists of $C^4H^6S^2$, and is consequently equivalent to $C^4H^4 + 2HS$.

It appears to me that there is this analogy between mercaptan, alcohol, and sulphovinic acid, that each consists of etherine united to two atoms of an appropriate acid. Alcohol is a bihydrate, sulphovinic acid a bisulphate, and mercaptan a bisulphydrate of etherine. When mercaptan reacts with a metallic oxide, one atom of its hydrogen forms water with the oxygen; while an atom of its sulphur converts the metal into a sulphobase. Consequently, the formula of the mercaptide of mercury should be $HgS + C^4H^4 + HS$, which would make it equivalent to a sulphydrate of etherine and mercury.

This explanation is consistent with that given by Zeisse, but it appears to me that in reacting with the bioxide or bichloride of mercury, two atoms of mercaptan must be decomposed, and a compound formed, represented in composition by the following formula: $HgS^2 + 2E + 2HS$.

Mercaptan is a colourless ethereal liquid, with a peculiarly penetrating odour, and a sweet ethereal taste. Its specific gravity is 0.842, and its boiling point is about 144°.

By its properties and composition, independently of its reaction with metals, it seems entitled to be classed with the other ethereal compounds of etherine, as ***bisulphydric ether***.

OF SOME ADDITIONAL COMPOUNDS OF ETHERINE.

It has been already stated that etherine forms two compounds with sulphuric acid, the oil of wine of Hennel, or sulphate of etherine, and sulphovinic acid. Magnus alleges that he has formed two acids, which differ in composition from sulphovinic acid in containing an atom less of water, but are isomeric with each other. One of the acids in question was formed by the addition of anhydrous sulphuric acid to alcohol.

A liquid, identical in properties with sulphuric ether, is formed by the reaction of phosphoric acid with alcohol. Pelouze has ascertained that during this process an acid analogous to the sulphovinic is produced, which he calls ***phosphovinic***.

Dumas and Boullay have ascertained that by passing a current of ammoniacal gas through oxalic ether, an acid is produced, which unites with the ammonia. To this acid they have given the name of ***oxalovinic***.

TABLE OF THE COMPOSITION OF THE COMPOUNDS OF ETHERINE.

NAMES.		FORMULA.
Etherine		$= 4C+4H=E.$
Sulphuric ether		$= E+\dot{H}.$*
Alcohol		$= E+2\dot{H}.$
Sulphate of etherine, (oil of wine)		$= 2E+2\dddot{S}+\dot{H}.$
Sulpho-vinic acid.	According to Berzelius	$= E+2\dddot{S}+\dot{H}.$
	According to Magnus	$= E+2\dddot{S}+2\dot{H}.$
Two isomeric sulphovinic acids discovered by Magnus		$= E+2\dddot{S}+\dot{H}.$
Phospho-vinic acid,	According to Pelouze	$= E+\overset{\cdot\cdot\cdot\cdot\cdot}{\underline{P}}+2\dot{H}.$
	According to Liebig	$= E+\overset{\cdot\cdot\cdot\cdot\cdot}{\underline{P}}+\dot{H}.$
Oxalovinic acid, probably		$= E+2\underline{\dddot{C}}.$†
Nitric ether‡		$= E+\dddot{N}+\dot{H}.$

---

* The student is reminded that each dot over a symbol signifies an atom of oxygen. Hence $\dot{H}$ stands for water, $\dddot{S}$ for sulphuric acid, $\dddot{N}$ for hyponitrous acid, $\overset{\cdot\cdot\cdot\cdot\cdot}{\underline{P}}$ for phosphoric acid; the dash *under* the letter, representing a double atom of phosphorus, the five dots over it, five atoms of oxygen.

† Dumas and Boullay, the discoverers of this acid, do not seem to have ascertained the quantity of water which it contains.

‡ More properly hyponitrous ether.

NAMES.	FORMULA.
Oxychlorocarbonic ether	$= E+C^2ClO^3+\dot{H}$.
Oxalic ether	$= E+\underline{\dddot{C}}+\dot{H}$.
Benzoic ether	$= E+\dot{Bz}+\dot{H}$.*
Acetic ether	$= E+\overline{A}+\dot{H}$.†
Formic ether	$= E+\overline{F}+\dot{H}$.
Tartaric ether	$= E+\overline{T}+\dot{H}$.
Citric ether	$= E+\overline{C}+\dot{H}$.
Malic ether	$= E+\overline{M}+\dot{H}$.
Protochlorine ether	$= E+Cl$.
Bichlorine ether	$= E+2Cl$.
Perchlorine ether	$= E+4Cl$.
Sulphocyanic ether, probably	$= E+S^2C^2N$.
Chlorohydric ether	$= E+HCl$.
Iodohydric ether	$= E+HI$.
Bromohydric ether	$= E+HBr$.
Mercaptan	$= E+2HS$.

OF PYROACETIC SPIRIT.

During the distillation of acetic acid from the acetates, they are partially resolved into a carbonate which remains in the retort, and a limpid, volatile, inflammable liquid, called *pyroacetic spirit.*

The formula of acetic acid being . . . . $C^4H^6O^3$,
deducting that of carbonic acid . . . . $C\ \ O^2$,
we get the liquid in question, of which the formula is . . . C^3H^6O.

OF PYROXYLIC SPIRIT.

Allusion has been made at page 286 to *mytheline*, as one of the varieties of the group, designated by the common epithet of *carbohydrogen.* It was stated to have been elaborated from a volatile liquid called *pyroxylic spirit*, now alleged to be a bihydrate of mytheline. Hence this spirit bears the same relation to mytheline, as alcohol to etherine. It was consequently conjectured that by processes analogous to those employed to produce ethers having etherine for a base, analogous ethereal compounds, having mytheline for a base, might be produced. This conjecture has been verified to a great extent; but the limits of this work do not admit of my giving the details.

---

* Bz has been assumed as the symbol for *benzule*, the radical of benzoic acid. Hence Bz with a dot over it, is the symbol of benzoic acid.

† It will be seen that, following the plan of Berzelius, I have adopted the initial letter with a dash *over* it, as the symbol for each of the vegetable acids.

SECTION XI.

OF THE ACETOUS FERMENTATION.

It is well known that liquors produced by the vinous fermentation, are liable to acidity, in consequence of the presence of an acid spontaneously generated, and of which I have already treated, page 451, under the name of acetic acid. When thus originating it forms the acid of the well known liquid called *vinegar* in commerce, from the French *vinaigre*, sour wine. The process during which vinous liquids are spontaneously converted into vinegar is called the *acetous fermentation.* It was probably in this form that acidity first attracted human observation; and hence the name of the principle to whose presence it was due, has been extended to a class, of which some of the members differ from it extremely.

The acetous fermentation, as well as the vinous, appears to be promoted by a peculiar ferment, vulgarly called the *mother of vinegar.* Usually the acetous fermentation follows the vinous, but yet occasionally supersedes this process. When distillers are not careful to preserve their mashing vessels free from sour matter, left from previous operations, it is well known that their wash becomes sour, and that the product in alcohol is proportionably lessened. Vegetable infusions often become sour, when there has been no intervening indication of the vinous fermentation.

Alcohol, per se, is not liable to be acidified, but, with the addition of water and fermentable matter, may be converted into vinegar.

It is alleged that the strongest liquors make the strongest vinegars.

The vinegars of commerce vary with the liquors from which they have been procured, in almost every other respect excepting their acid, which, when separated by distillation, always forms the pure diluted acetic acid, known in pharmacy as *distilled vinegar.* This is a very improper name; as vinegar is actually decomposed by the process of distillation.

OF ANIMAL SUBSTANCES.

Ultimate analysis, in the case of animal as well as in that of vegetable matter, has a tendency to confound substances extremely different in their nature. Hydrogen, oxygen, carbon, and nitrogen are the elements of the most nutritive and the most poisonous animal principles; of the milk of the cow, and the venom of the viper. Our wonder on observing this similitude in the composition of substances, in their nature so discordant, is, however, increased, when we learn that the carbonization of our own blood, in contact with an alkali, may be productive of a principle, which united to one of the elements of water, forms the deadly prussic acid.

It would seem, whatever may be the rationale, as if there were an analogy between the effects of an animal gland, and the Voltaic circuit. Within the influence of either, the affinities which prevail under ordinary circumstances, give place to others which are productive of new combinations. This demonstrates that, although all matter may invariably exercise attraction of gravitation, yet the elective affinity which gives rise to changes both within and without the precincts of vitality, may be adventitious, and dependent on occult and complicated contingencies.

By the digits, by the eight notes in music, or by a few beads in the kaleidoscope, an almost infinite variety of combinations may be produced, each affecting the senses differently. It cannot then be surprising that consequences, no less various, should, in the case of the vegetable and animal creation, arise from a limited number of elementary principles.

Effects of Ignition on Animal Matter.

The only difference between the results of the destructive ignition of animal and vegetable matter, is that the prevalence of nitrogen in the former, renders this substance, or its combinations in ammonia or prussic acid, the frequent products of the decomposition of animal substances; and that the charry residuum of this decomposition is much more difficult to incinerate.

Peculiarities in the Composition of Animal Matter.

In the state of subphosphate of lime, bones contain a larger proportion of calcium and phosphorus, than exists in any vegetable product: and sulphur is evolved far more copiously during the spontaneous decomposition of flesh, than from vegetable matter under the same circumstances. Hence the smell of sulphydric acid attendant on animal putrefaction.

PROXIMATE ANIMAL SUBSTANCES.

Animal substances may be conveniently arranged under the four following heads: 1. *Substances which are neither resinous, oily, nor acid;* 2. *Animal resins;* 3. *Animal oils or fats;* 4. *Animal acids.*

◆

SECTION I.

OF ANIMAL SUBSTANCES, WHICH ARE NEITHER RESINOUS, OILY, NOR ACID.

OF FIBRIN.

Fibrin exists in chyle and in blood, and forms the principal part of muscular flesh. It is, therefore, the most abundant animal substance.

To obtain fibrin, Thenard advises that blood, as it flows from a vein, should be beaten with a handful of birch twigs. Each of these will become loaded with a number of long red filaments, which, by washing in cold water, are whitened and purified.

Fibrin is solid, white, insipid, inodorous, heavier than water, neither acid nor alkaline, while wet, elastic, when dry, hard and brittle, becoming of a yellowish hue. In its natural state, it contains four-fifths of its weight of water. By distillation, it yields much carbonate of ammonia, and a very bulky shining charcoal, which it is difficult to burn; but which, being burnt, leaves a residuum of the phosphates of lime and magnesia, and of the carbonates of lime and soda. Exposed in an open vessel to the action of water, occasionally renewed, fibrin putrefies, leaving more or less residue, accordingly as it may have been more or less interlarded with fat.

With respect to the action of the acids and alkalies upon fibrin, it may be sufficient to mention that, in general, it is decomposed by them, when they are concentrated, and dissolved by them, when dilute. Nitric acid, however, even when dilute, decomposes fibrin, causing it to yield nitrogen gas.

The action of concentrated sulphuric acid upon fibrin, deserves particular notice. When fibrin is subjected to its own weight of this acid, a perfect solution ensues, unaccompanied by the extrication of sulphurous acid. The solution, thus obtained, being diluted with water, boiled nine hours, and the acid saturated with chalk, affords a liquid, which, by filtration and evaporation, yields a peculiar white matter, which the discoverer, Mr. Braconnot, has named *leucin*, from λευκος, white.

The symbolic formula for fibrin, is $C^{13}H^{14}O^{5}N^{3}$.

OF ALBUMEN.

Albumen, though not entering so largely as fibrin into the animal organization, is more extensively distributed throughout it. United in various proportions with water, and with minute portions of saline matter, it constitutes the whites of eggs, whence its name, the serum of the blood, the liquor of the pericardium, and that evolved in dropsy, or by blisters. It is also an ingredient in chyle, and probably, more or less, in all the animal fluids.

According to Berzelius, however, there is a difference between the properties of albumen, as existing in the serum of the blood, and in the white of eggs.

Albumen is capable of existing both as a solid and as a liquid, being convertible from the latter into the former state by heat. The habitudes of solid albumen with acids or fire, are very similar to those of fibrin.

Solid albumen is not soluble in water; hence, to procure it liquid, recourse must be had to it in its natural state of liquidity. In this form, it is sufficiently alkaline to affect tests. Its obvious properties are universally known, as seen in the white of eggs. Exposed in the Voltaic circuit, it coagulates about the wire proceeding from the positive pole.

The phenomenon of the coagulation of albumen by heat, is not well explained. As the addition of an alkali causes it to re-dissolve, Dr. Thomson suspects its fluidity to be due to the presence of soda. Were his conjecture correct, cold water ought to coagulate it, and heat could not, unless the alkali were volatile.

Albumen forms insoluble compounds with most of the acids. Hence a very minute quantity of it disseminated in water, may be detected by nitric acid. Neither acetic nor phosphoric acid have this effect; but paraphosphoric acid immediately coagulates albumen. Hence this substance is an excellent test to discriminate between the two last mentioned acids. Albumen is precipitated from blood by acids, and the precipitate redissolves on adding ammonia.

Albumen precipitates nearly all the oxides, chlorides, and iodides of the metals proper from their solutions, and, agreeably to analysis made by Rose, the metals exist in the precipitate in the state of oxide. As these precipitates are almost destitute of action on the animal system, albumen has been suggested as an antidote for metallic poisons.

Albumen is an excellent test, and likewise the best antidote for corrosive sublimate. Ferrocyanuret of potassium is, according to Turner, as good a test for albumen as corrosive sublimate, if not better; provided acetic acid be added to neutralize any alkali.

Albumen is coagulated by alcohol, and precipitated by tannin. It is of great use in clarifying syrups. By mixing with them while viscid, it envelops any feculent matter with which it may come in contact; and the union continues until coagulation ensues, and renders it easy to effect a removal of the coagulum. It clarifies wine in like manner, excepting that the coagulation results in this case from the presence of alcohol.

As obtained from blood or eggs, albumen forms a very tenacious lute by admixture with hydrate of lime.

The formula, representing the composition of albumen, is, according to the analysis of Gay-Lussac and Thenard, $C^{17}H^{13}O^{6}N^{2}$, while that of Prout would make it $C^{15}H^{14}O^{6}N^{2}$.

284. *Experimental Illustrations.*

In different vessels, corrosive sublimate and albumen are dissolved in water. The contents of the vessels being mingled, a precipitate appears.

OF GELATIN.

Gelatin, agreeably to Thenard, never makes a part of the animal humours, though solid gelatin is to be found in muscle, skin, cartilages, tendons, and aponeuroses. The membranes yield a great quantity, the bones about one-third of their weight.

According to Berzelius, gelatin never exists ready formed in the bodies of animals, but is produced during the exposure to heat and water which is generally employed to obtain it. He states that this conversion takes place without any perceptible escape of gas, and may be effected in close, as well as in open vessels. The nature of the reaction does not appear to be understood.

It is alleged by the same author that, when a solution of gelatin is kept for some time at a little below the boiling point, it gradually loses the property of forming a jelly by refrigeration.

Gelatin displays no acidity, nor does it, like albumen, show any trace of an alkali. It is heavier than water, tasteless, colourless, and inodorous; and its ultimate elements, resulting from igneous analysis, are the same as those of albumen and fibrin. In its habitudes with water it differs from albumen, being very soluble in boiling water, and difficult to dissolve in cold water. One part, dissolved in one hundred of boiling water, stiffens completely on cooling, and one part, with one hundred and fifty of boiling water, becomes gelatinous as it cools.

Several of the salts and acids have the property of precipitating gelatin, but not so unequivocally as to be good tests of its presence. It is much more soluble in acetic acid than in water. It is partially precipitated by alcohol, and totally by tannic acid. Alcohol precipitates it by taking away water; tannic acid, by forming an insoluble substance analogous to leather.

Chlorine also produces, with gelatin, a flocky precipitate.

Gelatin is not acted on by alcohol, oils, or ether.

By a process similar to that in which leucin was evolved from fibrin, Braconnot obtained from gelatin, a peculiar crystallizable sugar, which resembles grape sugar, and yet is not susceptible of the vinous fermentation. It differs from common grape sugar also, in affording ammonia by destructive distillation, which demonstrates that nitrogen is among its constituents.

Gelatin, in the form of joiner's glue, is manufactured for the purposes of the arts, from the clippings of skins, and from the ears of animals butchered for the market. These substances, being freed from hair and oil, and boiled for a long time, yield a solution of glue; which, when sufficiently concentrated by ebullition, hardens as it cools.

The gelatin of bones may be obtained by the solvent power of water when exalted by heat and pressure, as in the celebrated digester of Papin. Or, the phosphate of lime being removed by chlorohydric acid, the gelatin becomes soluble in boiling water.

Ichthyocolla, or isinglass, is obtained from the air bladder of a species of sturgeon; and inferior kinds, from other parts of the same or of other fishes. It is the finest specimen of glue or gelatin. The glue from bones is alleged by Thenard to be the next best in quality, and is now prepared extensively in France.

Gelatin is the principal ingredient in soup. Hence, by evaporation, soup may be reduced to the consistence of a glue, which comprises, within a very small space, the materials for regenerating, with the aid of hot water, the soup from which it was obtained. In the indurated state to which I have alluded, gelatin has been sold under the name of portable soup. Calf's foot jelly consists principally of gelatin.

Agreeably to the analysis of Gay-Lussac and Thenard, the composition of gelatin differs from that of albumen, in containing about five per cent. less carbon, and between three and four per cent. more oxygen.

285. *Experimental Illustration.*

A solution of tannic acid being poured into a solution of glue or ichthyocolla, a precipitation ensues.

OF CASEUM.

This appellation has been given by Braconnot to the curd obtained from milk by the rennet, which appears distinct in its properties from any other animal substance.

Agreeably to the observations of Proust, caseum is capable of undergoing a species of fermentation, by which it is partially converted into two substances, which he designates as *caseous oxide* and *caseous acid*, and to which he ascribes the agreeable flavour of cheese, when sufficiently old.

Caseous oxide and caseous acid were also supposed to be produced by the fermentation of gluten.

According to Braconnot, the insolubility of caseum in the state in which it is generally known, is dependent on the presence of some foreign body, generally an acid or earthy substance. As it exists in cheese, it is combined with acetic and lactic acid. From these acids it may be separated by boiling the cheese in water, and adding a solution of bicarbonate of potash to the coagulated mass, which is not taken up by the water. An effervescence, occasioned by the escape of carbonic acid gas, takes place, and a solution of the caseate of potash is obtained. This solution by evaporation yields a substance resembling fish glue, which may be kept for a great length of time without undergoing any change. Mr. Braconnot conceives that this caseate would prove very valuable for food, especially during long voyages; since, by dissolving it in water, with the addition of a little sugar and butter, or even without this latter substance, it would be a tolerable substitute for milk.

By adding diluted sulphuric acid to the solution of caseate of potash, an insoluble sulphate of caseum is precipitated.

A solution of caseum may be obtained from this, by the addition of an aqueous solution of carbonate of potash, just sufficient to saturate the sulphuric acid which liberates the caseum, and enables it to combine with water. By pouring into this solution about its own weight of alcohol, a small portion of the caseum, together with the sulphate of potash and other impurities, precipitates; while the remainder of the caseum continues dissolved in a state approaching nearly to purity, though still retaining a small portion of potash.

According to Braconnot, pure caseum, when dry, resembles gum arabic in appearance, and in its solubility in water. It acts both as an acid and a base; since it reddens litmus paper, and forms combinations with the alkalies which are soluble in water; while its compounds with acids are insoluble in that liquid.

Braconnot has alleged that caseous oxide, for which he has proposed the name of *aposepidine*, may be produced by the putrefaction of any animal substance. The same chemist has denied that the substance, called caseous acid, is deserving of this name. He conceives it to be a mixture of caseous oxide with various substances, and with an oil, to which he attributes the pungency of old cheese.

Aposepidine, according to Braconnot, is inodorous, nearly insipid, crystallizable, and soluble in water, especially when hot.

OF CANTHARIDIN.

This name has been given to the vesicating principle of cantharides, first isolated by Robiquet, and subsequently by Gmelin, Thierry, and others.*

According to Robiquet, it exists in the insect in union with a green oil, and associated with a brown and black matter; also with acetic and uric acid, and phosphate of magnesia. It is elaborated by subjecting powdered cantharides to successive portions of hydric ether in a stoppered glass funnel, until this solvent passes colourless. The first portions, which appear oily, being set aside, the rest are to be exposed to the distillatory process, in order to remove the ether. The residuum deposites crystals of cantharidin, which is stated to be white, inodorous, insoluble in water, and more soluble in hot than in cold alcohol; hence, by refrigeration, it is separated in needle-formed crystals, or, if the solution be too much concentrated, in plates. Cantharidin is likewise soluble in hydric ether, oil of turpentine, oil of olives or of sweet almonds, and in melted lard. Minute portions applied to the skin quickly produce rubefaction, and afterwards pustules. It fuses at 378°, and at a higher temperature sublimes, and condenses in brilliant crystalline needles, sustaining only a partial decomposition. Unless when heated, concentrated sulphuric acid does not dissolve it; and when the solution is effected, the addition of water throws down the cantharidin in the form of needle-shaped crystals.

---

* Ann. de Chimie, vol. 76, page 302.

Cantharidin is soluble in nitric and chlorohydric acid only when heated, and consequently, by refrigeration, separates from them in crystals. In the cold it is not soluble in liquid ammonia, but dissolves in dilute solutions of caustic potash or soda, and may be precipitated in the usual form of needle-shaped crystals by the addition of acetic acid. The composition of cantharidin is carbon 68.6, nitrogen 9.89, hydrogen 8.43, and oxygen 13.15.

OF MUCUS.

The term mucus, in an enlarged sense, is applied to a fluid which lubricates the mouth, œsophagus, stomach, intestines, and other passages of the body. It differs from albumen in not being liable to coagulation; nor does it gelatinize by concentration. Neither tannic acid nor corrosive sublimate affect it. Subacetate of lead renders its solution opake, and afterwards causes a precipitation.

Agreeably to the opinion of Berzelius, mucus should be considered as a generic appellation, designating several species, of which the chemical qualities vary with the animal functions in which they are employed.

OF UREA, OR THE CRYSTALLIZABLE MATTER OF URINE.

A substance exists in the urine of animals, to which the appellation of urea has been given.

Urine is evaporated to the consistence of syrup by a very delicate management of fire. When quite cold, nitric acid is to be added by little and little. The mixture is to be agitated, and placed in an ice bath to congeal; when a crystalline combination is formed by the acid with the urea. The crystals thus procured are to be washed with ice-cold water, and cleansed by allowing them to drip, and by pressing them between the folds of blotting paper. The nitrate of urea, thus obtained, is afterwards re-dissolved, mingled with charcoal, strained from the charcoal, and decomposed by carbonate of potash. The resulting solution, being evaporated to dryness, is treated with very pure alcohol, which takes up nothing but urea, and, by concentration, affords it in pure crystals.

It is to the presence of this substance that urine owes the power of yielding carbonate of ammonia by distillation.

Urea is nearly inodorous, but when tasted, causes a sensation of coolness, similar to that produced by nitre. It is very soluble in water, and crystallizes in transparent colourless prisms. It appears in some cases to act as a base; since it combines both with nitric and oxalic acid.

Urea has been noticed at page 294. It consists of $C^2N^2O^2H^4$. Its elements are, therefore, in the proportion requisite to form an atom of cyanic acid, an atom of ammonia, and an atom of water.

When the vapour of hydrous cyanic acid is brought into contact with gaseous ammonia, the acid and alkali unite, forming a cyanate of ammonia, which contains probably an atom of water. When a solution of this cyanate is evaporated, or when the cyanate itself is exposed to the air, ammonia is evolved, and urea remains. It is, therefore, probable, that the cyanate of ammonia, obtained by the last mentioned process, is a dicyanate, consisting, as this name implies, of one atom of acid, and two of ammonia. By parting with one atom of ammonia, it is reduced to the state of a neutral cyanate, identical in composition and properties with urea.

Urea may also be obtained by decomposing the cyanate of lead by ammonia.

The following formula, contrasted with that above given for urea, shows the identity of the composition of urea, and of cyanate of ammonia when containing an atom of water.

Cyanate of ammonia$=NC^2O+NH^3+HO$.

OF ANIMAL SUGAR.

Sugar is an animal, as well as a vegetable product. Milk whey, evaporated to dryness, and subjected afterwards to water, the resulting solution being clarified by albumen, and concentrated by evaporation, yields a species of saccharine matter in crystals, called *sugar of milk* or *lactin*. It differs from common sugar in being much less soluble in boiling water, and in not being fermentable.

The Tartars are said to ferment mares' milk, and thus to convert it into an intoxicating liquor; yet, in this process, the sugar of milk is alleged to have no participation. The fermentation of milk is not found to lessen the quantity of the sugar.

Diabetic sugar, according to Dr. Henry, is crystallizable, and more analogous to that of vegetables than to the sugar of milk.

* * *

SECTION II.

OF ANIMAL RESINS.

Under this head, *resin of bile*, *ear-wax*, *ambergris*, and *castor* are placed.

OF RESIN OF BILE.

By adding one part of chlorohydric acid to thirty-two parts of ox bile, a resinous matter is dissolved, and by subsequent filtration and evaporation may be isolated. It melts at about the same heat as spermaceti. It is soluble in water, as well as in alcohol, and is of course deficient in a very essential characteristic of resinous substances.

It is alleged that this resin is to be considered as the cause of the smell, and, in great measure, of the colour and taste of the bile.

OF CERUMEN, OR EAR-WAX.

According to Henry, it melts at a gentle heat, sinks into paper like oil, is very combustible, and burns with a white smoke, emitting an ammoniacal odour, and leaving little charcoal. With water, it forms a sort of emulsion. Alcohol dissolves five-eighths of it, and the remainder has the properties of albumen. The residue of the solution in alcohol, after the evaporation of this solvent, resembles the resin of bile.

OF AMBERGRIS.

This substance is found floating on the sea within the tropics. Its origin is not well known; though it is supposed to be produced by the whale. It is not strictly a resin. Alcohol extracts from it a peculiar substance, called *ambreine*, which is analogous to *cholesterine*, a substance obtained from biliary calculi.

OF CASTOR.

Castor is found in two small bags, in the inguinal regions of the beaver. It contains a substance analogous to the resin of bile.

◆

SECTION III.

OF ANIMAL OILS OR FATS.

Fat differs from oil only in consistency. Tallow, lard, and all the other varieties of fat may be considered as concrete oils.

Chemically, there is little difference between vegetable and animal oils. In neither is nitrogen a constituent, and in both hydrogen and carbon are the predominant elements, oxygen being an ingredient only in small proportion.

Animal oils are generally less disposed to fluidity than vegetable oils; yet, like these, they consist of a less fusible oil, called *stearin*, and a more fusible oil, called *elain*, into which they are susceptible of being separated by means of alcohol or cold.

From the cranium of the spermaceti whale, three oleaginous substances are obtained; one harder than tallow, and called spermaceti; the others known in commerce as winter and summer strained oils. As, in very cold weather, the latter becomes concrete, the former is under such circumstances strained from it. Winter strained oil is the elain of the fat of the whale.

It is well known that, when oils are subjected to the temperature of ignition, they are resolved into certain aëriform substances. The converse of the change thus effected was accomplished by Berard. One volume of carbonic acid, ten volumes of carburetted hydrogen, and twenty volumes of hydrogen being mixed, and passed through a red-hot porcelain tube, a deposition of white crystals took place, which were lighter than water, soluble in alcohol, and fusible by heat into a liquid resembling a fixed oil.

By Dobereiner, a similar result is said to have been obtained, by subjecting coal gas and aqueous vapour to the temperature of ignition.

OF BUTYRIN, PHOCENIN, AND HIRCIN.

These appellations have been given to three peculiar oils; the first discovered in butter, the second in the oil of the porpoise, the third in the fat of sheep and goats.

It has already been mentioned that, during the process of saponification, oils are acidified; the resulting acids uniting with the alkalies, and forming soap. In the case of animal oils, margaric, stearic, and oleic acids are usually produced; but that other acids are produced in particular instances, will appear from the list I shall give of acids generated from animal substances.

OF GLYCERINE, OR THE SWEET PRINCIPLE OF OILS.

This is a transparent, colourless, inodorous, tasteless, inflammable, and soluble liquid, which is evolved from vegetable and animal oils during saponification.

By nitric acid, it is converted into oxalic acid. By sulphuric acid, it may be made to yield sugar, as fecula does under the same circumstances.

OF ADIPOCIRE.

On opening a grave at Paris, in which a large number of human bodies had been buried for many years, they were found to consist of a substance resembling spermaceti, to which the name of *adipocire* was given. It was afterwards found that, by exposing muscular flesh to running water, or to nitric acid, adipocire might be produced; and it was generally supposed to arise from a transmutation of fibrin. Gay-Lussac subsequently expressed the opinion, that adipocire is derived entirely from fatty matter previously existing in the flesh, the fibrin being removed by putrefaction.

Chevreul has since alleged that the substance in question is a soap, consisting of ammonia, potash, and lime, united with margaric acid in excess.

The quantity of adipocire stated to have been found in the grave at Paris, appears to me to have been much greater than can reasonably be ascribed to the fat of bodies, a majority of which must have been emaciated by disease. Besides, a case is noticed by Dr. Thomson, in which the flesh of a woman, buried in "a moss" in Scotland for more than 130 years, was chiefly converted into adipocire.

◆

SECTION IV.

OF ANIMAL ACIDS.

Johnson, in his Report for 1832 to the British Association, gives a list of twenty animal acids. Some others are mentioned under this head by distinguished authors, to which he does not allude. Also there are several acids, which, although existing in animal substances or produced from them, are classed with the vegetable or inorganic acids, as having been originally detected in vegetables or inorganic bodies. Yet, notwithstanding this formidable list of acids, there are very few treated of under the head of animal chemistry, to which I should deem it expedient to require the attention of the student.

The most interesting among the acids which are found in animals, are the sulphuric, chlorohydric, phosphoric, and acetic acids.

These have been sufficiently noticed under the head of inorganic or vegetable substances. Uric acid, which is an excrementitious animal product, is an object of interest, as the most frequent constituent of urinary concretions. The rosacic and purpuric acids derive some importance from their association with uric acid.

Butyric acid has pretensions to notice as existing in small proportion in butter.

It has been mentioned that the margaric and oleic acids are produced during saponification. They exist also in adipocire.

Sulphocyanhydric acid, though not mentioned among animal acids by Thenard, is said to exist in saliva.

The amniotic acid is found only in the liquor of the amnios of the cow. Benzoic acid has been detected in some kinds of urine. Formic acid exists in ants. Almost all the other acids are produced by heat, or by the action of nitric acid or of the fixed alkalies upon animal matter, and have been applied to no useful purpose, if we except the acids formed with cyanogen. These have been sufficiently dwelt upon in another part of this work. See pages 294 and 296.

I subjoin a list of the animal acids, indicating the substances from which they are obtained, and the agents in their production.

Uric acid, from certain urinary calculi.
Delphinic, from the fat of the dolphin.
Ceric, by distilling a wax soap with sulphuric acid.
Cetic, by saponifying spermaceti.
Ambreic, by treating ambrein with
Castoric, by treating castorin with
Purpuric, from uric acid, by the action of
Saccholactic, saclactic, or mucic, } from sugar of milk by } Nitric acid.
Cholesteric, from cholesterine by
Hippuric, from the urine of graminivorous animals.
Lactic, from sour milk, or the fermented juice of beets.
Formic, from ants, or from alcohol, sulphuric acid, and manganese by distillation.
Allantoic, from the liquor of the allantois of the cow.
Margaric and stearic, } from stearin by
Oleic, from elain by
Phocenic, from an oil of the porpoise by } the action of potash.
Butyric, caproic, and capric, } from butter by
Hircic, from the fat of the sheep or goat by
Sebacic, from suet or lard by heat.

OF URIC ACID.

Uric acid constitutes the deposition from certain urines under the form of a yellow powder, which attaches itself so firmly to the recipient, as to be removed with difficulty even by friction: and all those calculi, or those layers in calculi which are yellowish, and of which the powder resembles sawdust, are formed of it. The white, in the excrement of birds, consists likewise of this acid. It has been found in cantharides, in the excrement of the silk worm, and, in large quantities, in that of the eagle and boa constrictor, united to ammonia. Combined with soda, it forms arthritic concretions.

It is procured by treating the yellow sediment of urine, the yellow urinary calculi, or the excrements containing it, with a solution of potash in excess, and adding chlorohydric acid to the resulting liquid. This acid neutralizing the alkali, the uric acid, dissolved in it, is precipitated in flocks which, after a time, are changed into brilliant plates. This precipitate is to be washed upon a filter with water, till the washings are not rendered turbid by nitrate of silver, and afterwards gently dried.

Properties.—Obtained by the process abovementioned, uric acid is a tasteless, inodorous, yellowish-white powder, insoluble in alcohol, slightly soluble in hot water, and requiring of this last mentioned liquid, at 60° ten thousand times its weight for solution.

The compounds which it forms with the earths and alkalies may be decomposed by almost all the acids, even by carbonic acid. It has scarcely any effect upon litmus.

Uric acid dissolves in nitric acid, and yields, by evaporation to dryness, a residuum of a purple colour.

The composition of uric acid, according to the recent analysis of Liebig, is $C^5N^2H^2O^3$. Thomson, however, supposes that the hydrogen and two atoms of the oxygen are due to the presence of water, and that uric acid, when *anhydrous*, is destitute of hydrogen, and contains but one atom of oxygen.

Wohler has shown that the acid obtained from uric acid by heat, and heretofore designated by the name of *pyro-uric*, is in fact *cyanuric acid*. See page 294.

OF PURPURIC ACID.

An acid is produced by the reaction of nitric with uric acid, which was called purpuric; as it was supposed to give rise to the purple colour which has been mentioned as a mean of detecting uric acid.

OF ROSACIC ACID.

The lateritious sediment, obtained from the urine in certain cases of disease, has been alleged to contain an acid, called rosacic from its rosy colour.

It appears, however, to be now generally admitted, that the acid called rosacic, consists of uric acid modified by the presence of some foreign body.

OF LACTIC ACID.

To the acid of sour milk, the appellation of *lactic* acid has been given, from *lac*, the latin for milk. This acid is generated by the fermentation of rice water, beet juice, or an infusion of nux vomica. It acts upon iron and zinc, causing the evolution of hydrogen. This acid was first distinguished as peculiar by Scheele. Subsequently, it was by many chemists considered as acetic acid disguised by the presence of some foreign matter; but J. Gay-Lussac and Pelouze have recently shown by an elaborate examination, that it is a peculiar acid.

It presents the singular phenomenon of an organic acid, not only capable of existing in the anhydrous state, but also of crystallizing in that state; while, when combined with water, it does not crystallize.

The formula of the uncrystallizable hydrous acid, is $C^6H^4O^4+2HO$; that of the crystallizable anhydrous acid, $C^6H^4O^4$.

OF FORMIC ACID.

This acid was originally obtained from ants. It appears to exist in them naturally.

Formic acid has been resolved into carbonic oxide and water by Dobereiner. The synthesis of this acid has been effected by this chemist, by distilling crystallized tartaric acid with sulphuric acid and black oxide of manganese.

Formic acid may be obtained by adding to one part of sugar in an alembic, three parts well pulverized peroxide of manganese, and three parts of sulphuric acid, diluted with its weight of water. The acid should be added in three successive portions. At first, the effervescence is so great as to require the vessel to have fifteen times the capacity which would be necessary to contain the materials when quiescent. Formic acid, associated with formic ether, is brought over by distillation. It may be saturated with chalk or an alkali, and the resulting formiate decomposed, and the acid isolated, by distillation with ten parts by weight of sulphuric acid, diluted with four parts of water.

Dobereiner alleges that formic acid and formic ether highly merit the attention of physicians and chemists. He represents this acid as an excellent reagent for separating the noble metals from solutions, in which they are intermingled with other metals proper. If a solution, containing one or more noble metals, be elevated nearly to the temperature of ebullition, on adding an alkaline formiate, the noble metals will be immediately and entirely precipitated in a very minute state of division. At the same time, by ascertaining the weight of the gas simultaneously evolved, that of the metal thrown down may be determined.

The bichloride of mercury, when in solution, is converted into calomel with so much facility, and in a state of division so minute by formic acid or formiate of soda, that Dobereiner recommends their employment in the preparation of that protochloride.

If the same quantity of sulphuric acid and manganese be mingled with six parts of alcohol, the process being in other respects the same as that for formic acid above described, formic ether becomes the predominant product. It is freed from formic acid by magnesia, from alcohol by a small quantity of water, and from water by chloride of calcium. By a more exensive contact with water, formic ether is decomposed, and alcohol and ormic acid are generated.

Formic acid has a pungent taste, and a peculiar sharp odour. It is omposed of C^2HO^3.

OF COMPLEX ANIMAL LIQUIDS AND SOLIDS.

SECTION I.

OF ANIMAL LIQUIDS.

OF BLOOD.

From the proximate elements of animal matter, we proceed to treat of the more complex substances into which such elements enter as ingredients. Among these blood is pre-eminently important. The properties of blood are well known. Within the sphere of vitality it is always fluid. Its colour is bright red in the arteries, and dark red in the veins. Its taste is saltish, and its smell faint. The specific gravity of human blood is 1.0527; that of ox blood 1.056.

In the state in which it exists in the veins and arteries, blood consists of albumen, fibrin, and small portions of various salts, of a multitude of minute red globules, and a liquid nearly colourless, in which the other ingredients are dissolved or suspended. Although too minute to be distinguished by the naked eye, the globules have been ascertained, by the aid of the microscope, to be constituted of a nucleus of fibrin, surrounded by a colouring matter, to which the name of *hematosin* has been given. In order to obtain hematosin, Berzelius recommends that the crassamentum, previously cut into thin slices, and subjected to pressure between the folds of blotting paper to free it from serum, should be agitated in water. By these means a solution of the hematosin is obtained, from which it may be separated in the solid state by evaporation.

Hematosin appears almost black when in mass, but becomes red by pulverization. In properties and chemical composition it agrees nearly with albumen, being coagulated and rendered insoluble by heat, and consequently precipitated from its solutions. Nevertheless it di from the last mentioned principle in containing a mi proportion of iron.

The colour of the blood was at one time ascribed to subphosphate of iron, dissolved in the serum by means of an alkali. Subsequently, this explanation was found to be erroneous, and Brande adduced some striking facts in favour of the opinion that the matter in question, like vegetable dyes, owes its colour to unknown causes. It was afterwards discovered by Engelhart, that, although iron exists neither in the fibrin nor serum of the blood, it is associated with the red globules. This he proved, not only by demonstrating its existence in the products of their incineration, but by passing chlorine through a solution of them, by which means a modification ensued, which rendered the iron susceptible of detection by the usual tests. Engelhart also ascertained that, from a liquid containing albumen and other soluble animal substances, oxide of iron cannot be precipitated by the alkalies, sulphydrate of ammonium, or an infusion of galls.

It has been suggested by Dr. Turner, that the colouring matter of the blood might be sulphocyanide of iron; but in the last edition of his Chemistry, he appears to have abandoned that idea, and to lean to the opinion of Brande, abovementioned, principally upon the ground that the iron, forming only $\frac{1}{200}$th of the weight of the hematosin, must be inadequate to produce the striking red colour of the liquid in question. Considering the wonderful influence of minute portions of matter, and especially of sulphocyanide of iron in affecting the colour of bodies, I am not convinced of the insufficiency of the iron in the globules to produce their hue.

It has been stated that the colour of the blood is of a much brighter red in the arteries than in the veins. This difference has been ascribed to its exposure to oxygen in the lungs, and consequent decarbonization. Lately Dr. Stevens has alleged that the colour of hematosin is naturally dark, but is rendered darker by acids, while by salts it is reddened; that the florid hue of arterial blood is due to saline matter dissolved in the serum; and that the dark colour acquired in the veins arises from carbonic acid. The observations of Dr. Stevens have been so far confirmed by those of Dr. Turner, as that a portion of a coagulum of arterial blood, deprived of its serum, and the saline matter associated with it, acquired the appearance of venous blood; but recovered its florid colour when restored to its serum, or when immersed in a solution of bicarbonate of soda. These facts, if confirmed, must awaken much attention, but unfortunately do not diminish our theoretic ignorance; since the influence of the saline matter and acids on hematosin is anomalous and inexplicable.

Blood, after its removal from the animal, is gradually resolved into two portions, one of which, called *serum*, is a transparent liquid of a pale yellow colour; while the other is solid, and retains the red colour of the blood, being called the *crassamentum* or *clot*. Of this phenomenon no satisfactory explanation has yet been given.

The crassamentum is composed chiefly of fibrin, mixed with hematosin to which it owes its colour.

The serum consists of water, holding albumen and small portions of various salts in solution, and, like other liquids containing that principle, may be coagulated by heat, when it yields a liquor called *serosity*, which, according to Berzelius, consists of water, holding in solution, albumen, soda, the chlorides of sodium and potassium, lactate of soda, and a peculiar animal matter with a trace of phosphoric acid.

Potash and soda diminish the tendency of the blood to coagulate, while acids hasten it. The alkalies act by rendering the fibrin more soluble, the acids by coagulating the albumen.

Almost all metallic salts, excepting those of the alkalies and earths, produce a precipitation in blood, in consequence of the affinity which exists between albumen, and oxides, chlorides, and acids. Alcohol, by taking hold of the water, precipitates all the other matter.

OF CHYLE.

Chyle resembles blood in resolving itself into a coagulum, and a liquid like serum, which, according to Dr. Prout, consists partly of albumen, but principally of *incipient albumen*. The coagulum, according to Vauquelin, is imperfect fibrin; but Brande considers it as more allied to caseous matter.

The opinions of Prout and Vauquelin derive support from the consideration that, as chyle is destined to become blood, it may be reasonably expected to contain the principal constituents of that liquid, in a state advancing towards maturity.

Of Respiration.

Respiration, so far as it is dependent upon mec
principles, was sufficiently explained under the
atmospheric pressure. Chemistry informs us that
this process, a portion of oxygen gas disappears
replaced by carbonic acid, varying in quantity
season or time of day in which the observation
made, and with the nature of the animals whose
may be analyzed. In the case of the human spec
quantity is nearly adequate to compensate the dir
of oxygen; while in that of some animals, it is s
be little more than half as much.

The observations which have been made respec
nitrogen, have shown that the influence of respira
the quantity of that gas in the breath is variable.
respired by different animals, and even by the sa
mal at different periods, the proportion of nitro
been found sometimes unaltered, sometimes gre
other times less, than before respiration.

It has been generally supposed that the oxyger
air drawn into the lungs, is converted into carbon
by uniting with carbon presented to it by the blo
that, if the nitrogen be increased or diminished,
consequence of a corresponding exhalation or abs
of this gas by the same liquid. Yet experimen
dence and plausible arguments have been addu
Dr. Edwards in favour of the opinion, that an abs
of oxygen and nitrogen and an evolution of carbo
and nitrogen are simultaneously effected in the
He supposes that the oxygen, being absorbed by
terial blood, passes into the circulation, and is gr
carbonized; and, returning with the venous blood
lungs, is evolved in the state of carbonic acid. N
is conceived to be in like manner absorbed, carr
the circulation, and evolved again; the quantity
being sometimes greater, sometimes less, than t
sorbed; at other times, just equal to it.

It appears from the late inaugural thesis of my
friend and pupil Dr. R. E. Rogers, of which the
ments were for the most part performed in the lab
of this Institution, that neither exhaustion nor the
212° are capable of extricating carbonic acid from
blood. It was also proved by him that oxygen, n

and nitrous oxide are absorbed in different proportions by it, yet are not replaced in any degree by carbonic acid. When, however, venous blood is enclosed in a recent cellular or serous membrane, and the whole placed in a vessel of atmospheric air or oxygen; while a portion of the medium is absorbed, carbonic acid is disengaged from the blood, indicating a specific agency in the tissue employed. In this respect the experiments were conceived to imitate, closely, the function of respiration in the class of mammalia. It was also shown by Dr. Rogers, that a tissue, interposed between two gases or liquids, influences both the rate and direction in which they become intermingled by permeating the tissue; also that, during their passage through such organic tissues, caloric is evolved to an extent sufficient to justify the opinion that animal heat may be partially due to an analogous process.

It has been ascertained that, during the union of carbon and oxygen, as much heat is evolved, as will thaw ninety-six times the weight of the carbon in ice. During twenty-four hours, a man has been estimated to emit as much carbonic acid, as would require for its formation nearly eleven ounces of carbon, and consequently the emission of as much heat as would thaw sixty-six pounds of ice.

Considerations similar to these, led Black, Lavoisier, Crawford, and others, to view the carbonization of oxygen gas in the air breathed by animals, as the only source of animal heat. This opinion appeared afterwards to be invalidated by the allegations of Mr. Brodie that, in animals recently killed, refrigeration could not be retarded by sustaining their respiration artificially.

The observations of other physiologists have not confirmed those of Brodie. Besides, it has generally been considered incredible that the carbonization of oxygen should not cause the extrication of heat within, as well as without the precincts of vitality. Nevertheless, a series of very accurate experiments, made by Dulong, demonstrates that more heat is evolved by animals, than would be afforded by the combustion of the carbon imparted by them to the air. The animals subjected to observation, were placed in a vessel surrounded by water, so that the whole of the heat generated by them could be known; while by means of an appropriate apparatus, the supply of air afforded to them was regulated and measured. The quantity of carbonic acid generated, and of oxygen gas consumed, was likewise ascertained. The difference between these quantities was ascribed to the union of a portion of the oxygen with hydrogen, presented to it in the blood.

The heat yielded by the oxygen thus converted into water, and that converted into carbonic acid, was considered as comprising the whole which could be derived from respiration. This was found by Mr. Dulong never to be less than 69 per cent., nor more than 80 per cent., of the whole heat emitted by the animal. The heat which could be ascribed to that portion of the oxygen which was converted into carbonic acid, was, in the case of carnivorous animals, never less than 49, nor more than 65 per cent. of the whole heat generated; but in the case of frugivorous animals, it was never less than 65, nor more than 75 per cent. of the whole.

The conclusions of Mr. Dulong are founded on the estimate of the heat produced by the combustion of carbon and hydrogen, made by Lavoisier and Laplace. Mr. Despretz repeated the investigations of Mr. Dulong, founding his estimate of the heat produced by the combustion of oxygen gas with carbon and hydrogen, on a new series of experiments.

I subjoin a summary statement of the deductions of Mr. Despretz.

He infers, that there is an exhalation of nitrogen in all cases during respiration; the quantity being greater from frugivorous, than from carnivorous animals.

That the volume of the carbonic acid disengaged, never equals that of the oxygen which disappears; and that the disparity in this respect is greater in young animals than in adults.

That the quantity of heat which can be ascribed to the union of oxygen with carbon and hydrogen, is never less than 72 per cent., nor greater than 90 per cent., of the heat produced by the animal.

Upon the whole, it appears from the experiments of Dulong and Despretz, that the heat arising from respiration, is from 10 to 30 per cent. less than the whole of the heat generated by animal life. If these results are to be relied upon, the remainder must be ascribed to the fixation of the fluid matter of the blood, and that change of capacity, so often observed to be attendant upon combination and decomposition. If the temperature of substances undergoing the vinous fermentation, can be augmented by these causes, it is reasonable to suppose that they may contribute to the heat of animals.

In page 438, I mentioned the facts ascertained by Dr. Mitchell of the Medical Institute, respecting the permeability of caoutchouc by gases. Agreeably to one doctrine, carbon is supposed to be abstracted from the blood within the lungs; agreeably to another hypothesis, oxygen passes into it, and carbonic acid, previously formed, is emitted. To both views, the impermeability of the membrane was an alleged obstacle; but the experiments of Mitchell in the first place, and those of Rogers abovementioned, latterly, seem to have removed all difficulty arising from this source.

Dr. Turner, in his Chemistry, page 978, 5th edition, makes the following remarks. "The difficulty which formerly stood in the way of both theories of respiration, arising from the supposed impermeability of animal membranes by gases, has been entirely removed by the researches of Drs. Faust and Mitchell. It fully appears from their experiments, and of the accuracy of their principal results I am satisfied from personal observation, that animal membranes, both in the living and dead subject, both in and out of the body, are freely penetrable by gaseous matter."*

It has been a question, by what means are plants supplied with their constituent carbon, and how is the ratio of the oxygen to the nitrogen in the atmosphere preserved, notwithstanding the incessant consumption of oxygen by animals, by combustion, and other chemical processes? It was suggested by Dr. Ingenhauz, that plants at the same time acquire carbon and supply oxygen, by decomposing the carbonic acid, well known to exist in the air. It follows that by a species of respiration, they produce an effect the opposite of that produced by animals, who give out carbon and absorb oxygen. By Ellis and others, this result has been controverted; as, agreeably to their experiments, plants were not found competent to effect the alleged change. But, according to Daubeny, these experiments are not to be considered as conclusive; since the plant was included so long as to become unhealthy. He has satisfied himself that, in fine weather, a plant, if confined in the same portion of air night and day, and duly supplied with carbonic acid during the sunshine, will go on adding to the proportion of oxygen present so long as it continues healthy, or at least up to a certain point; the slight increase of carbonic acid which takes place during the night, bearing no considerable proportion to the degree in which the contrary effect is observable during the day.

---

* Page 980, Dr. Turner observes, alluding to the above mentioned chemists, "the American philosophers are entitled to the merit of advancing from the detached facts of others to the establishment of a principle."

Considering the quantity of oxygen generated by a very small portion of a tree or shrub so introduced, he sees no reason to doubt that the influence of the vegetable, may serve as a complete compensation for that of the animal kingdom; especially since this same function appears to belong to every plant which has come under his view, whatever may be its structure or organization.

OF ANIMAL SECRETIONS.

Several liquids are described in treatises of chemistry, which are secreted by animal organization; as, for instance, lymph, synovia, saliva, the humours of the eye, tears, the gastric and pancreatic juices, bile, sweat, urine, and milk. An account of these substances, so far as it can be afforded without chemical principles or illustrations, belongs to the chair of the Institutes. It is my duty to explain their chemical properties and composition, as far as it may be practicable or expedient.

But, unfortunately, the analyses which have been made of the substances under consideration by eminent chemists are contradictory, and the opinions entertained of them, fluctuating; and were it otherwise, I should deem it injudicious to occupy the attention of students with details which experienced chemists cannot recollect, unless in cases in which their attention has been particularly excited. I shall, therefore, conclude this part of animal chemistry with an account of the *gastric juice*, *milk*, *urine*, *bile*, and *sweat*.

Gastric Juice.—The gastric juice is a transparent liquid, having a somewhat bitter taste. As obtained from the stomach of an animal killed while fasting, it is neither acid nor alkaline; but it has been alleged that it owes its solvent powers to the presence of chlorohydric and acetic acid, secreted during digestion. This opinion has received support from the detection of chlorohydric and acetic acid in the stomach of animals killed during digestion; and it has been shown by Teidemann and Gmelin, that, at the temperature of the body, those acids are capable of dissolving all digestible substances employed as food.

Milk.—This liquid needs no description. Its density and qualities vary not only in different animals, but at different times in the same animal, according to health or food. It spontaneously separates into cream, curd, and whey.

Milk is composed of caseum, butter, sugar of milk, different salts, especially phosphates, and a little acid. The butter and a portion of the caseum are only suspended in the milk in a state of minute division, whence its opacity; but another portion of the caseum appears to be dissolved. When evaporated, a pellicle is formed on its surface. By distillation it yields water slightly contaminated with milk. If heated daily, it does not spoil for a long time. It is extremely coagulable by acids and alcohol, and likewise by the coating of the calf's stomach, to which the name of rennet has been applied. It is probable that this coagulation, when produced by acids, is due to the insolubility of the compounds formed by those bodies with caseum. The effect produced by rennet has been attributed to the acids of a portion of the gastric juice, which it is supposed it may retain. But it must be evident that only a minute proportion of acid could be thus held; and Berzelius has shown that of rennet, previously macerated in water to remove every thing soluble in that liquid, 1 part will coagulate 1800 of milk, though losing only $\frac{1}{25}$th of its weight. It is, therefore, inferred by him that caseum, like fibrin and albumen, is susceptible of two different states; in one of which it is soluble, in the other, insoluble.

Whey, as I have stated, contains sugar of milk; and besides this, some other animal matter, with phosphates and chlorides.

The milk of women contains less caseous matter, and more sugar, than cows' milk. It yields more cream, but not of a kind convertible into butter.

Urine.—This secretion is a very complicated fluid, being apparently secreted for the purpose of carrying off impurities, received into or formed in the blood.

Agreeably to an analysis made by Berzelius, the composition of urine is as follows:—

Water	933.00
Urea	30.10
Uric acid	1.00
Free lactic acid, lactate of ammonia, and animal matter not separable from them	17.14
Mucus of the bladder	0.32
Sulphate of potassa	3.71
Sulphate of soda	3.16
Phosphate of soda	2.94
Phosphate of ammonia	1.65
Chloride of sodium	4.45
Chloride of ammonium	1.50
Earthy matters with a trace of fluoride of calcium	1.00
Silicic acid	0.03
	1000.00

Bile.—According to the analysis of Gmelin, the bile of the ox contains water; a substance having the odour of musk; cholesterine; biliary resin; a crystalline substance which he calls taurin; biliary sugar (the picromel of Thenard); colouring matter; a substance analogous to gluten; caseous and salivary matter; albumen; mucus; osmazome; an extractive matter insoluble in alcohol; margaric and oleic acid; a new acid, to which the appellation of cholic has been given; bicarbonates, acetates, oleates, margarates, cholates, sulphates and phosphates of potash and soda; phosphate of lime; chloride of sodium; and a minute quantity of carbonate of ammonia.

Berzelius considers the composition of the bile as much more simple than would be inferred from the analysis above given. He conceives that a great portion of the substances abovementioned, may be produced by the agents employed for their evolution, and that it is probable that the bile contains the albuminous substances of the blood, so modified as to be readily convertible into a great variety of compounds.

Sweat.—According to Thenard, sweat contains much water, a little acetic acid, chloride of sodium, perhaps also chloride of potassium, a very little phosphate of lime, a trace of iron, and a quantity of animal matter almost too small to be appreciated. Berzelius regards sweat as water holding in solution the chlorides of sodium and potassium, lactic acid, lactate of soda, and a little animal matter.

◆

SECTION II.

OF ANIMAL SOLIDS.

For reasons already specified in the case of the liquid secretions, I do not deem it expedient to enter into a detail of the chemical properties and composition of all the substances which might come under this head. I will only state a few facts respecting some of them.

OF URINARY CALCULI.

These may be divided, according to Henry, into six species.

I. Calculi which are chiefly composed of uric acid, or urate of ammonia:

II. Calculi principally composed of the ammoniaco-magnesian phosphate (phosphate of ammonia and magnesia):

III. Calculi consisting for the most part of phosphate of lime:

IV. Calculi containing principally carbonate of lime:

V. Calculi which derive their characteristic property from oxalate of lime; and

VI. Calculi composed of the substance discovered by Dr. Wollaston, and called by him *cystic oxide*.

To these may be added, calculi containing two or more of the above mentioned ingredients in a state of admixture; and those in which they form distinct layers, or concentric strata.

Dr. Marcet informs us, that when uric acid predominates in a calculus, a fragment, no larger than a pin's head, being held in the blowpipe flame by a slender pair of platinum tongs, blackens, emits a smoke having a strong and characteristic odour, is gradually consumed, and leaves a minute quantity of white ashes, which are usually alkaline.

Another mode of recognising this calculus, is to subject a small portion, in a watch glass, to a few drops of caustic potash over a lamp. The uric acid is immediately dissolved, leaving the other ingredients untouched. From the solution thus formed, almost any acid will cause a white precipitate of pure uric acid.

Lastly, if a minute portion of calculus, containing uric acid in the smallest proportion, be exposed to a drop of nitric acid, and heated to dryness, the residuum will display a beautiful purple, or carmine colour.

When phosphate of lime predominates in a fragment of calculus, it first blackens, but soon after becomes perfectly white, and is very difficult of fusion before the blowpipe. Calculi of this kind are readily dissolved by dilute chlorohydric acid, and the solution formed, when the acid is not in great excess, may be precipitated by oxalate of ammonia.

If a calculus, consisting principally of the ammoniaco-magnesian phosphate, be subjected to a gentle heat, or moistened with caustic potash, an ammoniacal odour will be perceptible.

There is a species of calculus, which, when exposed to the blowpipe flame, bubbles up and melts easily into globules, usually pearly but sometimes transparent. This species is called the *fusible calculus*. It is, principally, a mixture of phosphate of lime, and the phosphate of ammonia and magnesia. It is readily soluble in dilute chlorohydric acid, from which the lime may be precipitated by the addition of oxalic acid; and by adding ammonia, a precipitate ensues of the phosphate of ammonia and magnesia.

The calculus, in which oxalate of lime predominates, is sometimes called the *mulberry calculus*, from its resemblance to a mulberry. The heat of a spirit lamp is generally adequate to destroy the acid in this calculus, and to develop quicklime, which may of course be detected by turmeric.

Cystic oxide is recognised, *chemically*, by its great solubility in acids and alkalies.

The calculus composed of carbonate of lime is seldom found.

Besides these calculi there are the *zanthic oxide calculus* and *fibrinous calculus*. The former derives its name from its yellow colour, the latter from the resemblance of its properties to fibrin. Both are extremely rare.

OF ARTHRITIC CONCRETIONS.

Arthritic concretions were shown by Wollaston to contain uric acid and soda. Urate of lime and chloride of sodium have since been demonstrated to exist in them by Vogel.

OF SKIN.

Besides the intermediate tissue called rete mucosum, the human skin consists of the epidermis and true skin. The former resembles coagulated albumen in its chemical properties. Of the latter, the greater part, by boiling in water, may be converted into gelatin. Hence its utility in the manufacture of glue.

OF BONES.

Besides oil, of which the marrow is mainly constituted, bones consist of cartilage, indurated by phosphate and carbonate of lime. The two last mentioned constituents may be removed by diluted nitric or chlorohydric acid.

The cartilage retains the shape of the bone, after the removal of the other constituents. Besides the substances just mentioned, bones contain minute portions of other matter, as will appear from the following analysis of Berzelius.

Cartilage completely soluble in water, and convertible into gelatin by boiling - -	32.17
Vessels - - - - - -	1.13
Subphosphate of lime, with a little fluoride of calcium - - - - -	53.04
Carbonate of lime - - - -	11.30
Magnesia, either as phosphate or as carbonate	1.16
Soda, with a little chloride of sodium -	1.20
	100.00

Beef bones differ from those of man in containing only a third of the quantity of carbonate of lime, and in abounding in the calcareous and magnesian phosphate to a proportionably greater extent.

In addition to the ingredients in the abovementioned list, traces of sulphate of lime, alumina, silica, and oxide of iron were discovered by Hatchett, Fourcroy, and Vauquelin.

OF BRAIN.

The brain contains in 10,000 parts, according to an analysis of Vauquelin:—

Water	8000
White fatty matter	453
Red fatty matter	70
Albumen	700
Osmazome, a substance to which meat gravy is supposed to owe its savour	112
Phosphorus	150
Acids, salts, and sulphur	515
	10,000

According to M. Couerbe, who has recently made a chemical examination of the brain, the fatty matters consist of the following substances, viz, *cholesterine*, and four principles, not previously known, which he proposes to call *cerebrote*, *stearoconote*, *cephalote*, and *eleencephole*. These principles all consist of carbon, hydrogen, oxygen, and nitrogen, combined with between two and three per cent. severally of phosphorus and sulphur.

Such is the best account which it has pleased God to enable the brain of man to give of its own chemical constitution.

It is to be regretted that, of all studies to which the human mind has been directed, self-analysis, whether moral or physical, seems the most beyond its powers.

OF THE PUTREFACTIVE FERMENTATION.

To that species of spontaneous decomposition which is called putrefactive, animal substances, in general, are much more disposed than vegetable; and the effluvia which they emit, during the change, are much more offensive. The presence of phosphorus and sulphur contributes greatly to the fetor of animal putrefaction. On the other hand, few animal substances are susceptible of the vinous or acetous fermentation.

The presence of water, or of its elements, seems indispensable to the spontaneous decomposition of organic substances. In no instance is either the vinous, acetous, or putrefactive fermentation induced in substances which are perfectly dry. The effect of desiccation in preserving meat and fruits, sufficiently proves the correctness of this allegation. It is, probably, by paralyzing the activity of the water in meat, that salt favours its preservation; and the beneficial influence of sugar upon preserves may in like manner be explained.

When, in addition to water, nitrogen is a constituent, the tendency to putrefaction is increased. Gluten and yeast, which contain nitrogen, are very liable to an extremely offensive putrefaction. To their deficiency in this principle, Dr. Turner ascribes the indisposition of oils to putrescency; but I conceive their freedom from water, and incapacity to unite with it, to be the true cause.

The insusceptibility of the vegetable alkalies of decomposition, while containing both hydrogen, oxygen, and nitrogen, may arise partly from their sparing solubility in water, and partly from the predominance of carbon in their composition.

Although heat to a certain extent is necessary to putrefaction, it may be arrested by a high temperature, as well as by frost. In the one case, water being vaporized is removed; in the other, being congealed, becomes inert. We are unable to explain the peculiar efficiency of this liquid in promoting the spontaneous decomposition of organic products in all its forms. It seems as if certain affinities which exist between the ultimate elements of many vegetable and animal substances, although suspended by the inexplicable powers of vitality, resume their operation as soon as those powers cease, with greater or less activity, according to the nature of the substance, and the softening influence of heat and moisture.

Thenard alleges that water is not decomposed during putrefaction, but on the contrary generated.

Besides water, we may enumerate ammonia, with carbonic, acetic, and sulphydric acid, also carburetted and in some cases phosphuretted hydrogen, among the products of putrefaction.

Conclusion.

Of vegetable and animal chemistry, I must here take leave. Intrinsically, it consists of little more than a detail of facts. It is only from the splendid discoveries which have been made in the chemistry of inorganic matter, that we can hope for any theoretic elucidation of the properties of organic products, or of the means by which vitality creates, from sources so limited, such an infinite variety of interesting productions.

From the multiplicity of analyses, of which the results are so nearly alike as to baffle the efforts of the adept to remember them, it were utterly impracticable to impart a knowledge of the minutiæ of organic chemistry, during a course of instruction limited to four months. I am, however, consoled in recollecting, that it is that branch of chemical science, in which it is most easy for gentlemen of the medical profession to become their own instructers; as the subjects are within their reach, and the implements and agents for investigation are very simple, and may be obtained with, comparatively, little exertion and expense.

PRELIMINARY REMARKS

RESPECTING

THE TABLE OF EQUIVALENTS

IN THE FOLLOWING PAGES.

The equivalent of hydrogen is very light in comparison with those of other bodies, even agreeably to the idea, adopted by the English chemists, that water consists of one atom of each of its two ingredients. According to their estimate, the equivalent of carbon, which is the next to that of hydrogen in the table, is six times heavier; and those of oxygen and silicon, which are the next to carbon, are each eight times heavier than that of hydrogen. The equivalents of magnesium, nitrogen, sulphur, phosphorus, boron, calcium, sodium, chlorine, and potassium, are, severally, 12, 14, 16, 16, 11, 20, 24, 36, 40. The equivalent of iodine is 126 times as heavy as that of hydrogen, that of gold two hundred times as heavy. It follows, that unless analysis be effected with great accuracy, it may be as near the truth to assume that all equivalents are multiples of that of hydrogen, as to interpolate the fractional differences supposed to have been detected by chemists. If the numbers exhibited in the following table be correct, it follows, that in a majority of cases the equivalents of other substances are not exactly multiples of that of hydrogen. For the purpose of illustration, or for processes in the chemical arts, the nearest whole numbers to those ascertained by the most authentic analyses, will be found sufficiently accurate. The subjoined table has been compiled by my friend Dr. Bache, from data principally furnished by the fifth edition of Tu

Chemistry.* The numbers in this table being the result of investigations which were not within my reach when the Compendium went to press, do not correspond exactly with the numbers therein employed, which were taken from Brande's Table of Equivalents, published in London in 1832.

It may be expedient to state, that the word equivalent is in one meaning synonymous with the word atom, as used by many chemists, in the sense of the smallest portion of a body which can exist. The word equivalent has also been defined the least combining proportion of a substance, or any multiple of that quantity capable of combination; the least combining proportion being sometimes distinguished from others as the prime equivalent.

The numbers in a table of equivalents are also liable to be considered as indicative of the ratios in which the substances, with which they are associated respectively, must be used to effect combination or decomposition.

---

* Of this excellent work, which I recommend to those of my pupils who have leisure and disposition to read other books of Chemistry besides the Compendium, a new edition has just been published by Messrs. Desilver, Thomas & Co., from sheets furnished by the author. This republication has been made under the peculiarly vigilant and accurate superintendence of my friend above mentioned.

Note by Dr. Bache.—The following list is arranged in six tables. The first comprises the elementary bodies, and principal bi-elementary compounds, under which latter title the chief inorganic acids and bases are necessarily embraced. The second includes the principal organic bases, and the third a select list of organic acids. The chief acids and bases having been presented in these three tables, the more important single salts are given in the fourth, and examples of the double salts in the fifth. The sixth and last table comprises miscellaneous organic compounds, not acids nor bases.

LIST OF CHEMICAL EQUIVALENTS, THE EQUIVALENT OF HYDROGEN BEING ASSUMED AS THE STANDARD UNIT.

TABLE I.

*Elementary Bodies, and Principal Bi-elementary Compounds.**

NAMES.		Symbol.	Approximate equiv.	More accurate equiv.
ALUMINIUM	-	Al	14	13.7
sesquioxide (alumina)	$2Al+3O$		52	51.4
ANTIMONY (stibium)	-	Sb	64	64.6
sesquioxide (medicinal oxide)	$2Sb+3O$		152	153.2
antimonious acid	$2Sb+4O$		160	161.2
antimonic acid	$2Sb+5O$		168	169.2
sesquisulphide	$2Sb+3S$		176	177.5
bisulphide	$2Sb+4S$		192	193.6
persulphide	$2Sb+5S$		208	209.7
sesquichloride	$2Sb+3Cl$		236	235.46
bichloride	$2Sb+4Cl$		272	270.88
perchloride	$2Sb+5Cl$		308	306.3
ARSENIC	-	As	38	37.7
arsenious acid	$2As+3O$		100	99.4
arsenic acid	$2As+5O$		116	115.4
protosulphide	$As+S$		54	53.8
sesquisulphide	$2As+3S$		124	123.7
persulphide	$2As+5S$		156	155.9
protochloride	$As+Cl$		74	73.12
sesquichloride	$2As+3Cl$		184	181.66
BARIUM	-	Ba	69	68.7
protoxide (baryta)	$Ba+O$		77	76.7
bioxide	$Ba+2O$		85	84.7
sulphide	$Ba+S$		85	84.8
chloride	$Ba+Cl$		105	104.12
BISMUTH	-	Bi	71	71
protoxide	$Bi+O$		79	79
sesquioxide	$2Bi+3O$		166	166
sulphide	$Bi+S$		87	87.1
chloride	$Bi+Cl$		107	106 42
BORON	-	B	11	10.9
boracic (boric) acid	$B+3O$		35	34.9
fluoboric acid	$B+3F$		65	66.94
BROMINE	-	Br	78	78.4
bromic acid	$Br+5O$		118	118.4
CADMIUM	-	Cd	56	55.8
oxide	$Cd+O$		64	63.8
sulphide	$Cd+S$		72	71.9
CALCIUM	-	Ca	20	20.5
protoxide (lime)	$Ca+O$		28	28.5
bioxide	$Ca+2O$		36	36.5
chloride	$Ca+Cl$		56	55.92
CARBON	-	C	6	6.12
carbonic oxide	$C+O$		14	14.12
carbonic acid	$C+2O$		22	22.12
oxalic acid (anhydrous)	$2C+3O$		36	36.24
mellitic acid	$4C+3O$		48	48.48

---

* Several cyanides are included in this table, although they are not bi-el tary compounds; but as cyanogen performs the part of an element in its tions, it seemed best to place them here.

NAMES.		Symbol.	Approximate equiv.	More accurate equiv.
Carbon (continued)				
croconic acid	$5C+4O$		62	62.6
bisulphide	$C+2S$		38	38.32
cyanogen	$2C+N$		26	26.39
protochloride	$C+Cl$		42	41.54
dichloride	$2C+Cl$		48	47.66
sesquichloride	$2C+3Cl$		120	118.5
Cerium		Ce	46	46
protoxide	$Ce+O$		54	54
sesquioxide	$2Ce+3O$		116	116
Chlorine		Cl	36	35.42
protoxide	$Cl+O$		44	43.42
chlorous acid (Berzelius)	$Cl+3O$		60	59.42
peroxide	$Cl+4O$		68	67.42
chloric acid	$Cl+5O$		76	75.42
perchloric acid	$Cl+7O$		92	91.42
protochloride of sulphur	$Cl+S$		52	51.52
dichloride of sulphur	$Cl+2S$		68	67.62
trichloride of nitrogen	$3Cl+N$		122	120.41
Chromium		Cr	28	28
sesquioxide	$2Cr+3O$		80	80
chromic acid	$Cr+3O$		52	52
Cobalt		Co	30	29.5
protoxide	$Co+O$		38	37.5
4-3 oxide	$3Co+4O$		122	120.5
sesquioxide	$2Co+3O$		84	83
Columbium (tantalum)		Ta	185	185
bioxide	$Ta+2O$		201	201
columbic acid	$Ta+3O$		209	209
Copper (cuprum)		Cu	32	31.6
red or dioxide	$2Cu+O$		72	71.2
black or protoxide	$Cu+O$		40	39.6
superoxide	$Cu+2O$		48	47.6
disulphide	$2Cu+S$		80	79.3
protosulphide	$Cu+S$		48	47.7
Fluorine		F	18	18.68
Glucinium		G	18	17.7
oxide (glucina)	$G+O$		26	25.7[illegible]
Gold (aurum)		Au	200	199.2
protoxide	$Au+O$		208	207.2
bioxide	$Au+2O$		216	215.2
trioxide	$Au+3O$		224	223.2
trisulphide	$Au+3S$		248	247.5
protochloride	$Au+Cl$		236	234.62
trichloride	$Au+3Cl$		308	305.46
Hydrogen		H	1	1
protoxide (water)	$H+O$		9	9
bioxide (oxygenated water)	$H+2O$		17	17
sulphydric acid (sulphuretted hydrogen)	$H+S$		17	17.1
bisulphide	$H+2S$		33	33.2
ammonia	$3H+N$		17	17.15
fluohydric acid (hydrofluoric acid)	$H+F$		19	19.68
chlorohydric acid (muriatic acid)	$H+Cl$		37	36.42
bromohydric acid (hydrobromic acid)	$H+Br$		79	79.4
iodohydric acid (hydriodic acid)	$H+I$		127	127.3
selenhydric acid (hydroselenic acid)	$H+Se$		41	40.6
phosphuretted hydrogen	$3H+2P$		35	34.4
perphosphuretted hydrogen ?				
arseniuretted hydrogen	$3H+2As$		79	78.4
light carburetted hydrogen	$2H+C$		8	8.12
olefiant gas	$2H+2C$		14	14.24
etherine	$4H+4C$		28	28.48
ethule	$5H+4C$		29	29.48
paraffine eupione	constituents, united in the same ratio as in etherine, but equivalent unknown.			

NAMES.		Symbol.	Approximate equiv.	More accurate equiv.
HYDROGEN (continued)				
bicarburet	$3H+6C$		39	39.72
naphtha	$5H+6C$		41	41.72
naphthaline	$4H+10C$		64	65.2
paranaphthaline	$6H+15C$		96	97.8
camphene citrene	$8H+10C$		68	69.2
cyanhydric acid (hydrocyanic acid)	$H+(2C+N)$		27	27.39
IODINE		I	126	126.3
iodic acid	$I+5O$		166	166.3
periodic acid	$I+7O$		182	182.3
tritiodide of nitrogen	$3I+N$		392	393.05
IRIDIUM		Ir	99	98.8
protoxide	$Ir+O$		107	106.8
sesquioxide	$2Ir+3O$		222	221.6
bioxide	$Ir+2O$		115	114.8
trioxide	$Ir+3O$		123	122.8
IRON (ferrum)		Fe	28	28
protoxide	$Fe+O$		36	36
red or sesquioxide	$2Fe+3O$		80	80
black oxide	$(Fe+O)+(2Fe+3O)$		116	116
tetrasulphide	$4Fe+S$		128	128.1
disulphide	$2Fe+S$		72	72.1
protosulphide	$Fe+S$		44	44.1
sesquisulphide	$2Fe+3S$		104	104.3
bisulphide	$Fe+2S$		60	60.2
protochloride	$Fe+Cl$		64	63.42
sesquichloride	$2Fe+3Cl$		164	162.26
LEAD (plumbum)		Pb	104	103.6
dioxide	$2Pb+O$		216	215.2
protoxide	$Pb+O$		112	111.6
bioxide	$Pb+2O$		120	119.6
red oxide	$3Pb+4O$		344	342.8
sulphide	$Pb+S$		120	119.7
chloride	$Pb+Cl$		140	139.02
iodide	$Pb+I$		230	229.9
LITHIUM		L	6	6.44
oxide (lithia)	$L+O$		14	14.44
chloride	$L+Cl$		42	41.86
MAGNESIUM		Mg	12	12.7
oxide (magnesia)	$Mg+O$		20	20.7
chloride	$Mg+Cl$		48	48.12
MANGANESE		Mn	28	27.7
protoxide	$Mn+O$		36	35.7
sesquioxide	$2Mn+3O$		80	79.4
bioxide	$Mn+2O$		44	43.7
red oxide	$3Mn+4O$		116	115.1
varvicite[*]	$4Mn+7O$		168	166.8
manganic acid	$Mn+3O$		52	51.7
permanganic acid	$2Mn+7O$		112	111.4
protosulphide	$Mn+S$		44	43.8
protochloride	$Mn+Cl$		64	63.12
perchloride	$2Mn+7Cl$		308	303.34
MERCURY (hydrargyrum)		Hg	202	202
protoxide	$Hg+O$		210	210
bioxide (red precipitate)	$Hg+2O$		218	218
protosulphide	$Hg+S$		218	218.1
bisulphide	$Hg+2S$		234	234.2
protochloride (calomel)	$Hg+Cl$		238	237.42
bichloride (corrosive sublimate)	$Hg+2Cl$		274	272.84
protiodide	$Hg+I$		328	328.3

---

[*] This name has been given to an ore of manganese found in Warwickshire, England; whence its appellation.

NAMES.		Symbol.	Approximate equiv.	More accurate equiv.
MERCURY (continued)				
sesquiodide	$2Hg+3I$		782	782.9
biniodide	$Hg+2I$		454	454.6
bicyanide	$Hg+2(2C+N)$		254	254.78
MOLYBDENUM		Mo	48	47.7
protoxide	$Mo+O$		56	55.7
bioxide	$Mo+2O$		64	63.7
molybdic acid	$Mo+3O$		72	71.7
NICKEL		Ni	30	29.5
protoxide	$Ni+O$		38	37.5
sesquioxide	$2Ni+3O$		84	83
NITROGEN		N	14	14.15
nitrous oxide	$N+O$		22	22.15
nitric oxide	$N+2O$		30	30.15
hyponitrous acid	$N+3O$		38	38.15
nitrous acid	$N+4O$		46	46.15
nitric acid	$N+5O$		54	54.15
OSMIUM		Os	100	99.7
protoxide	$Os+O$		108	107.7
sesquioxide	$2Os+3O$		224	223.4
bioxide	$Os+2O$		116	115.7
trioxide	$Os+3O$		124	123.7
peroxide	$Os+4O$		132	131.7
OXYGEN		O	8	8
PALLADIUM		Pd	53	53.3
protoxide	$Pd+O$		61	61.3
bioxide	$Pd+2O$		69	69.3
PHOSPHORUS		P	16	15.7
oxide	$3P+O$		56	55.1
hypophosphorous acid	$2P+O$		40	39.4
phosphorous acid	$2P+3O$		56	55.4
phosphoric acid pyrophosphoric acid metaphosphoric acid	$2P+5O$		72	71.4
nituret	$P+N$		30	29.85
sesquichloride	$2P+3Cl$		140	137.66
perchloride	$2P+5Cl$		212	208.5
PLATINUM		Pl	99	98.8
protoxide	$Pl+O$		107	106.8
sesquioxide?	$2Pl+3O$		222	221.6
bioxide	$Pl+2O$		115	114.8
protochloride	$Pl+Cl$		135	134.22
bichloride	$Pl+2Cl$		171	169.64
POTASSIUM		Po	40	39.15
protoxide (potassa)	$Po+O$		48	47.15
trioxide	$Po+3O$		64	63.15
chloride	$Po+Cl$		76	74.57
iodide	$Po+I$		166	165.45
bromide	$Po+Br$		118	117.55
cyanide	$Po+(2C+N)$		66	65.54
RHODIUM		R	52	52.2
protoxide	$R+O$		60	60.2
sesquioxide	$2R+3O$		128	128.4
SELENIUM		Se	40	39.6
oxide	$Se+O$		48	47.6
selenious acid	$Se+2O$		56	55.6
selenic acid	$Se+3O$		64	63.6
SILICON		Si	8	7.5
silicic acid (silica)	$Si+O$		16	15.5
fluosilicic acid	$Si+F$		26	26.15
SILVER (argentum)		Ag	108	108
oxide	$Ag+O$		116	116
sulphide	$Ag+S$		124	124.1
chloride	$Ag+Cl$		144	143.42

NAMES.		Symbol.	Approximate equiv.	More accurate equiv.
Silver (continued)				
iodide	$Ag+I$		234	234.3
cyanide	$Ag+(2C+N)$		134	134.39
Sodium		So	24	23.3
protoxide (soda)	$So+O$		32	31.3
sesquioxide	$2So+3O$		72	70.6
chloride	$So+Cl$		60	58.72
iodide	$So+I$		150	149.6
bromide	$So+Br$		102	101.7
Strontium		Sr	44	43.8
protoxide (strontia)	$Sr+O$		52	51.8
bioxide	$Sr+2O$		60	59.8
chloride	$Sr+Cl$		80	79.22
Sulphur		S	16	16.1
sulphurous acid	$S+2O$		32	32.1
sulphuric acid	$S+3O$		40	40.1
hyposulphurous acid	$2S+2O$		48	48.2
hyposulphuric acid	$2S+5O$		72	72.2
Tellurium		Te	64	64.2
tellurous acid	$Te+2O$		80	80.2
telluric acid	$Te+3O$		88	88.2
Thorium		Th	60	59.6
oxide (thorina)	$Th+O$		68	67.6
Tin (stannum)		Sn	59	58.9
protoxide	$Sn+O$		67	66.9
sesquioxide	$2Sn+3O$		142	141.8
bioxide	$Sn+2O$		75	74.9
protosulphide	$Sn+S$		75	75
sesquisulphide	$2Sn+3S$		166	166.1
bisulphide	$Sn+2S$		91	91.1
protochloride	$Sn+Cl$		95	94.32
bichloride	$Sn+2Cl$		131	129.74
Titanium		Ti	24	24.3
oxide	$Ti+O$		32	32.3
titanic acid	$Ti+2O$		40	40.3
Tungsten (wolfram)		W	95	94:8
bioxide	$W+2O$		111	110.8
tungstic acid	$W+3O$		119	118.8
Uranium		U	217	217
protoxide	$U+O$		225	225
sesquioxide	$2U+3O$		458	458
Vanadium		V	69	68.5
protoxide	$V+O$		77	76.5
bioxide	$V+2O$		85	84.5
vanadic acid	$V+3O$		93	92.5
Yttrium		Y	32	32.2
oxide (yttria)	$Y+O$		40	40.2
Zinc		Zn	32	32.3
protoxide	$Zn+O$		40	40.3
peroxide?				
sulphide (blende)	$Zn+S$		48	48.4
chloride	$Zn+Cl$		68	67.72
Zirconium		Zr	34	33.7
sesquioxide (zirconia)	$2Zr+3O$		92	91.4

TABLE II.

Principal Organic Salifiable Bases.

NAMES.		Approximate equiv.	More accurate equiv.
Aricina*	$12H+20C+3O+N$	170	172.55
Brucia	$18H+32C+6O+N$	272	275.99
Cinchonia	$12H+20C+O+N$	154	156.55
Codeia	$20H+31C+5O+N$	260	263.87
Delphia?			
Emetia?			
Morphia	$18H+34C+6O+N$	284	288.23
Narceia?			
Narcotina?			
Quinia	$12H+20C+2O+N$	162	164.55
Strychnia	$16H+30C+3O+N$	234	237.75
Veratria	$22H+34C+6O+N$	288	292.23

TABLE III.

Principal Organic Acids.

NAMES.		Approximate equiv.	More accurate equiv.
Acetic	$3H+4C+3O$	51	51.48
Benzoic	$5H+14C+3O$	113	114.68
Camphoric	$8H+10C+5O$	108	109.2
Citric†	$2H+4C+4O$	58	58.48
Croconic.	See Table I. under carbon.		
Cyanhydric.	See Table I. under hydrogen.		
Gallic	$3H+7C+5O$	85	85.84
Kinic	$10H+15C+10O$	180	181.8
Lactic	$5H+6C+5O$	81	81.72
Malic†	$2H+4C+4O$	58	58.48
Meconic	$2H+7C+7O$	100	100.84
Mellitic.	See Table I. under carbon.		
Mucic (saclactic)	$5H+6C+8O$	105	105.72
Oxalic.	See Table I. under carbon.		
Racemic‡ (paratartaric)	$2H+4C+5O$	66	66.48
Succinic	$2H+4C+3O$	50	50.48
Sulphovinic (bisulphate of alcohol)	2 eq. acid+1 eq. alcohol	126	126.68
Tannic (from catechu)	$9H+18C+8O$	181	183.16
Tannic (from gall-nuts)	$9H+18C+12O$	213	215.16
Tartaric‡	$2H+4C+5O$	66	66.48

---

* This organic salifiable base was observed by Pelletier and Corriol in 1829, in a sample of cinchona bark, which had been substituted for the ordinary kinds of bark, and is very analogous to cinchonia and quinia in its properties. From the table, it will be seen that these three alkalies have such an analogy of composition, that they may be viewed as oxides of the same compound radical, the formula of which is $12H+20C+N$. (An. de Ch. et de Ph. li. 186.) TURNER.

† The citric and malic acids are isomeric.

‡ The racemic and tartaric acids are isomeric.

TABLE II.

Principal Simple Salts.

NAMES		Approximate equiv.	More accurate equiv.
ALUMINA.			
sulphate		92	91.3
tersulphate (constituent of alum)	3 eq. acid+1 eq. base	172	171.7
AMMONIA.			
acetate		68	68.63
carbonate		39	39.27
sesquicarbonate	3 eq. acid+2 eq. base	100	100.66
bicarbonate	2 eq. acid+1 eq. base	61	61.39
chlorohydrate (muriate of ammonia)		54	53.57
nitrate		71	71.3
oxalate		53	53.39
succinate		67	67.68
sulphate		57	57.25
sulphydrate		34	34.25
ANTIMONY, SESQUIOXIDE OF.			
tartrate (constituent of tartar emetic)		219	219.65
BARYTA.			
carbonate		99	98.82
hydrate		86	85.7
nitrate		131	130.85
sulphate		117	116.8
BISMUTH, PROTOXIDE OF.			
nitrate		133	133.15?
subnitrate?			
CADMIUM, OXIDE OF.			
nitrate		118	117.95?
sulphate		104	103.9?
CINCHONIA.			
acetate		205	206.03
chlorohydrate (muriate)		191	192.97
nitrate		208	210.7
sulphate		194	196.65
disulphate	1 eq. acid+2 eq. base	348	353.2
COBALT, PROTOXIDE OF.			
sulphate		78	77.6
CODEIA.			
chlorohydrate (muriate)		297	300.29?
COPPER, BLACK OR PROTOXIDE OF.			
acetate		91	91.06
diacetate	1 eq. acid+2 eq. base	131	130.68
tribasic* acetate	1 eq. acid+3 eq. base	171	170.28
dicarbonate	1 eq. acid+2 eq. base	102	101.32
nitrate		94	93.75
sulphate (blue vitriol)		80	79.7
GLUCINA.			
carbonate		48	47.82?

---

* Tribasic is a new word, employed to signify that a compound contains three equivalents of the base.

NAMES.		Approximate equiv.	More accurate equiv.
Iron, **protoxide of.**			
carbonate		58	58.12
nitrate		90	90.15
sulphate (green vitriol)		76	76.1
Iron, **red or sesquioxide of.**			
trisulphate	3 eq. acid+1 eq. base	200	200.3
Lead, **protoxide of.**			
acetate (sugar of lead)		163	163.06
diacetate	1 eq. acid+2 eq. base	275	274.68
tribasic acetate (Goulard's ext.)	1 eq. acid+3 eq. base	387	386.28
carbonate (white lead)		134	133.72
nitrate		166	165.75
Lime.			
bone-phosphate	3 eq. acid+8 eq. base	440	442.2
carbonate		50	50.62
nitrate		82	82.65
oxalate		64	64.74
sulphate		68	68.6
hydrated, with 2 eq. water (gypsum)		86	86.6
Lithia.			
carbonate		36	36.56
nitrate		68	68.59
sulphate		54	54.54
Magnesia.			
carbonate		42	42.82
nitrate		74	74.85
sulphate (Epsom salt)		60	60.8
cryst. with 7 eq. water		123	123.8
Mercury, **protoxide of.**			
acetate		261	261.43
nitrate		264	264.15
sulphate		250	250.1
Mercury, **bioxide of.**			
bisulphate	2 eq. acid+1 eq. base	298	298.2
subsulphate (turpeth mineral)	3 eq. acid+4 eq. base	992	992.3
nitrate		272	272.15
dinitrate (nitrous turpeth)	1 eq. acid+2 eq. base	490	490.15
Morphia.			
acetate		335	339.71
chlorohydrate (muriate)		321	324.65
sulphate		324	328.33
cryst. with 6 eq. water		378	382.33
Nickel, **protoxide of.**			
sulphate		78	77.6
Platinum, **protoxide of.**			
sulphate		147	146.9
Potassa.			
acetate		99	98.63
carbonate (salt of tartar)		70	69.27
sesquicarbonate	3 eq. acid+2 eq. base	162	160.66
bicarbonate	2 eq. acid+1 eq. base	92	91.39
chlorate		124	122.57
diarseniate	1 eq. acid+2 eq. base	212	209.7

NAMES.		Approximate equiv.	More accurate equiv.
Potassa (continued)			
diarsenite	1 eq. acid+2 eq. base	196	193.7
hydrate		57	56.15
iodate		214	213.45
nitrate (nitre or saltpetre)		102	101.8
sulphate (vitriolated tartar)		88	87.25
bisulphate	2 eq. acid+1 eq. base	128	127.85
tartrate (soluble tartar)		114	113.68
bitartrate (cream of tartar)	2 eq. acid+1 eq. base	180	180.11
Quinia.			
acetate		213	216.03
chlorohydrate (muriate)		199	200.97
nitrate		216	218.7
sulphate		202	204.65
disulphate (medicinal sulphate)	1 eq. acid+2 eq. base	364	369.2
Silver, oxide of.			
nitrate (lunar caustic)		170	170.15
sulphate		156	156.1
tribasic arseniate	1 eq. acid+3 eq. base	464	463.4
Soda.			
acetate		83	82.78
biborate (borax)	2 eq. acid+1 eq. base	102	101.1
carbonate		54	53.42
sesquicarbonate	3 eq. acid+2 eq. base	130	128.96
bicarbonate	2 eq. acid+1 eq. base	76	75.54
chlorate		108	106.72
diphosphate (medicinal phosphate)	1 eq. acid+2 eq. base	136	134
hydrate		41	40.3
iodate		198	197.6
nitrate		86	85.45
sulphate (Glauber's salt)		72	71.4
tartrate		98	97.78
Strontia.			
carbonate		74	73.92
hydrate		61	60.8
nitrate		106	105.95
sulphate		92	91.9
Strychnia.			
chlorohydrate (muriate)		271	274.17
sulphate		274	277.85
Thorina.			
nitrate		122	121.75
sulphate		108	107.7
Tin, protoxide of.			
sulphate		107	107
Veratria.			
chlorohydrate (muriate)		325	328.65 ?
sulphate		328	332.33
Yttria.			
carbonate		62	62.32 ?
nitrate		94	94.35 ?
sulphate		80	80.3 ?
Zinc, protoxide of.			
acetate		91	91.78
carbonate (calamine)		62	62.42
sulphate (*white vitriol*)		80	80.4

TABLE V.

Principal Double Salts.

NAMES.	Approximate equiv.	More accurate equiv.
Carbonate of lime and magnesia (Dolomite) 1 eq. carbonate of lime+1 eq. carbonate of magnesia	92	93.44
Sulphate of alumina and potassa (alum) 1 eq. trisulphate of alumina+1 eq. sulphate of potassa	260	258.95
cryst. with 24 eq. water - - - - - -	476	474.95
Tartrate of antimony and potassa (tartar emetic) 1 eq. tart. sesquioxide of antimony+1 eq. tart. of potassa	332	333.31
cryst. with 2 eq. water - - - - - -	350	351.31
Tartrate of potassa and soda (Rochelle salt) 1 eq. tartrate of potassa+1 eq. tartrate of soda	212	211.41
cryst. with 8 eq. water - - - - - -	284	283.41

TABLE VI.

Miscellaneous Organic Compounds, not Acids nor Bases.

NAMES.		Approximate equiv.	More accurate equiv.
Albumen?			
Alcohol - - - -	1 eq. etherine+2 eq. water	46	46.48
Asparagin - - - - -	$8H+8C+6O+2N$	132	133.26
Benzamide - - - -	$7H+14C+2O+N$	121	122.83
Benzule - - - - -	$5H+14C+2O$	105	106.68
Camphene.	(See Table I. under hydrogen.)		
Camphor - -	1 eq. camphene+1 eq. oxygen	76	77.2
Chloral - - - - - -	$9C+4O+6Cl$	302	299.6
Citrene.	(See Table I. under hydrogen.)		
Ethal - - - - -	$17H+16C+O$	121	122.92
Ether - - -	1 eq. etherine+1 eq. water, or 1 eq. ethule +1 eq. oxygen	37	37.48
Etherine.	(See Table I. under hydrogen.)		
Ethule.	(See Table I. under hydrogen.)		
Eupione.	(See Table I. under hydrogen.)		
Fibrin?			
Gelatin?			
Kreosote - - - - -	$4H+7C+O$?	54	54.84
Lactin (sugar of milk) -	$4H+5C+4O$	66	66.6
Lignin?			
Mannite - - - -	$7H+6C+6O$ (Liebig)	91	91.72
Margarine?			
Naphtha.	(See Table I. under hydrogen.)		
Naphthaline.	(See Table I. under hydrogen.)		
Oil of wine (sul. of etherine)	2 eq. acid+2 eq. ether.+1 eq. wat.	145	146.16
Oxamide - - - - -	$2H+2C+2O+N$	44	44.39
Paraffine.	(See Table I. under hydrogen.)		
Paranaphthaline.	(See Table I. under hydrogen.)		
Salicin - - - - -	$2H+2C+O$	22	22.24
Starch - - - - - -	$5H+6C+5O$	81	81.72
Stearine - - - - -	$70H+73C+7O$	564	572.76
Sugar - - - - -	$H+C+O$ (Prout)	15	15.12
	$5H+6C+5O$ (Thenard)	81	81.72
Urea - - - - - -	$4H+2C+2O+2N$	60	60.54

MEDICAL BOOKS

FOR SALE BY

JOSEPH G. AUNER,

BOOKSELLER AND STATIONER,

NO. 343 MARKET STREET—ABOVE NINTH ST.

PHILADELPHIA.

TEXT BOOKS.

COMPLETE SETS OF THE MEDICAL TEXT BOOKS.

In addition to the following Catalogue, all the new publications will be received as soon as published.

MEDICAL, CHEMICAL, BOTANICAL, &c.

Anatomical Examinations.
Anatomist's Vade Mecum.
Abercrombie on the Stomach, &c.
Abercrombie on the Brain.
Abernethy on Tumour.
Accum on Culinary Poisons.
Accum's Chemistry, 2 vols.
Accum's Mineralogy.
Acupuncturation, by Morand.
Aiken on the Cow Pox.
Alibert on Fevers.
Andral's Anatomy, 2 vols.
Armstrong on Typhus Fever.
" " Puerperal Fevers, Consumption, &c.
Armstrong's Practice, 2 vols.
Arnott's Elements of Physics, 2 vols.
Assalina on the Plague.
Averill's Surgery.
Ayre on the Liver.
Blanden's Anatomy, 2 vols.
Baudelocque's Puerperal Peritonitis.
Broussais' Pathology.
Boisseau on Fever.
Broussais on Insanity.
Bell and Condie on Cholera.
Bichat on Pathology.
Bichat on Life and Death.
Barton's Elements of Botany.
Bayle's Anatomy.
Beck's Chemistry.
Beck's Murray's Materia Medica.
Bichat's Anatomy and Physiology by Henderson.
Bostock's Physiology.
Buckland's Geology, 2 vols.
Burns's Midwifery.
Burns on Head and Neck.
Burns on Abortion.
Burns on Inflammation.
Bell on Baths and Mineral Waters.
Boyer on the Bones
Broussais on Inflammation, 2 vols.
Bell's Operative Surgery.
Bell on the Nerves.
Bell on the Urethra.
Bell on Ulcers.
Bell on Wounds.
Bell's Dissection, 2 vols.
Bell's Anatomy, 2 vols.
Bell's Engravings of the Bones.
Bell's Engravings of the Nerves.
Bell on the Teeth.
Bree on Asthma.
Bateman on Cutaneous Diseases.
Brande's Chemistry, by Webster.
Bailey's Morbid Anatomy.
Blackall on Dropsies.
Blane's Medical Logic.
Barton's Lectures on Materia Medica and Botany, 2 vols.
Bayle and Hollard's Gen. Anatomy.
Beck's Medical Jurisprudence, 2 vols.
Bigelow's Materia Medica.
Bancroft on Fever.
Beddoe's Observations.
Buchan's Domestic Medicine.
Boyer's Surgery, 2 vols.
Brande's Chemistry, by M'Nevin.
Bertin on the Heart.

J. G. AUNER'S CATALOGUE.

Brera on Verminous Diseases.
Belliol on Herpetic Affections.
Beddingfield's Practice.
Beclard's Anatomy.
Blake's Botany.
Bryant's Examinations in Anatomy and Physiology.
Brodie on the Joints.
Bell on the Nervous System.
Carpenter's Materia Medica.
Calhoun on Suspended Animation.
Caldwell's Cullen, 2 vols.
Cabanis on Certainty of Medicine.
Caldwell's Medical Theses.
Calvert's Phrenology.
Carlisle on Old Age.
Cazenave on Diseases of the Skin.
Casey's Flora.
Castle's Manual of Surgery.
Cholera, Bell and Condie on
Cholera, Kirk on
Cholera, Greenhow on
Cholera, Winslow on
Cholera, Suttetten on
Cholera, Torrey on
Chisholm on Malignant Fever.
Cheyne on Dropsy.
Corvisart on the Heart.
Coates' Popular Medicine.
Coxe's Medical Dictionary.
Cook on Nervous Diseases.
Coxe's Orfila's Chemistry.
Colhoun's Prout on the Urinary Organs.
Comstock's Botany.
Combe's Phrenology.
Combe on Insanity.
Comstock's Mineralogy.
Cook's Morgagni, 2 vols.
Cooper's Lectures on Surgery, by Tyrrell.
Clarke's Practice.
Carmichael on Venereal.
Curry on Cold Water.
Cooper and Traverse's Surgical Essays.
Copeland on the Rectum.
Curry's Synopsis.
Cooper on Dislocation.
Conversations on Chemistry.
Cooper on Dyeing.
Comstock's Grammar of Chemistry.
Cooper's (Samuel) First Lines of Surgery, 2 vols.
Cooper on the Joints.
Colle's Surgical Anatomy.
Cutbush's Observations.
Curry on Yellow Fever.
Cutler on Bandages.
Cheyne on Croup.
Coxe on Insanity.
Cook on White Mustard Seed.
Conversations on Natural Philosophy.
Cooper's Surgical Dictionary.
Coster's Physiological Practice.
Coxe's Refutation of Hervey's Claim.
Clarke on Consumption.
Christison on Poisons.
Chase on Hernia.
Chitty's Medical Jurisprudence.
Dupuytren's Surgery.
Duparque on Uterus.
Dunglison's Medical Dictionary.
Dunglison's Physiology, 2 vols.
Daniel on Fever.
Darwin's Zoonomia, 2 vols.
Darwin's Life.
Denman's Aphorisms.
Dewees' System of Midwifery.
Dewees on Treatment of Children.
Dewees on Diseases of Females.
Dewees' Essays on various subjects connected with Midwifery.
Dewees' Practice.
Desault's Surgery, 2 vols.
Denman's Midwifery, by Francis.
Duncan on Consumption.
Ducamp on Urine.
Doane's Surgery, Illustrated.
Dorsey's Surgery, 2 vols.
Desault on Fractures.
Dunglison on Hygiene.
Dunglison's Therapeutics.
Dunglison's Medical Student.
Dublin Dissector.
Ellis's Medical Formulary.
Eberle's Materia Medica and Therapeutics, 2 vols.
Esculapian Register.
Eberle's Practice, 2 vols.
Eberle's Notes.
Ewell's Medical Companion.
Edinburgh Dispensatory.
Eclectic and General Dispensatory.
English Maladies.
Edward's Manual of Surgical Anatomy.
Edward's Manual of Materia Medica, trans. by Togno and Durand.
Eaton's Manual of Botany.
Eberle on Children.
Fontana on Poisons.
Fordyce on Fever.
Ferriar's Medical Reflections.
Faithorn on Liver Complaint.
Francis' Denman's Midwifery.
Fitch's Dental Surgery.
Formulæ Selectæ.
Faraday's Chemical Manipulations.
Gamage on Fever.
Gerhard's Clinical Guide.
Gibson's Surgery, 2 vols.
Godman's Anatomical Investigations.
Gregory's Dissertation on Climates.
Gregory's Practice, 2 vols.
Good's Study of Medicine.

Good's Book of Nature.
Gardner on the Gout.
Gallup on Epidemics.
Gross on the Bones and Joints.
Gross' Pathological Anatomy.
Goupil on the New Medical Doctrine.
Graham on Indigestion.
Gooch's Midwifery.
Gooch on Females.
Greenhow on Cholera.
General Anatomy.
Gerhard on the Chest.
Goddard on the Arteries.
Goddard on the Nerves.
Haines' Catechism on Chemistry.
Hare's Chemistry.
Hall on Diagnosis.
Hall on Nervous System.
Hall on the Loss of Blood.
Healde's Pharmacopœia.
Henry's Chemistry, 2 vols.
Hooper's Medical Dictionary.
Hooper's Vade Mecum.
Heberden's Medical Commentaries.
Hamilton on Purgatives.
Hamilton on Mercury.
Hamilton's Midwifery.
Hornor's Special Anatomy, 2 vols.
Hall on Digestive Organs.
Hildenbrand on Typhus Fever.
Hale on Spotted Fever.
Hufeland on Scrofulous Diseases.
Hatin's Manual of Obstetrics.
Hutin's Manual of Phisiology.
Hennen's Military Surgery.
Hopkinson on the Arteries.
Hooper's Medical Examinations.
Haller's Physiology.
Horner's Practical Anatomy for the use of Dissectors.
Hosack's Practice.
Hall on Circulation of the Blood.
Innes on the Muscles.
James' Burns' Midwifery.
James' Merriman.
Johnson on Civic Life.
Johnson on the Liver.
Johnson on the Stomach.
Jaudon on Syphilis.
Johnson on Cancer.
Johnson on Change of Air.
Jones on Hæmorrhage.
Kramer on the Ear.
Laennec on the Chest.
Laennec on the Stethoscope.
Larry's Surgical Essays.
Larry's Military Surgery, 2 vols.
Littell on the Eye.
Liston's Surgery.
Lobstein's Practical Physician.
Lobstein on Phosphorus.
London Practice of Midwifery.
London Practice of Physic.
Le Gallois on Life.
Louis on Fever, 2 vols.
Louis on Phthisis.
Lieutaud's Practice.
Lawrence on Ruptures.
Lincoln's Botany.
Lobstein on the Sympathetic Nerve.
Larry on Injuries of the Head.
Mackintosh's Practice, 2 vols.
Manec's Plate of the Cerebro-Spinal Axis.
Mease on Sick Headache.
Meckel's Anatomy, 3 vols.
Meigs's Midwifery.
Majendie's Medical Formulary.
Majendie on Prussic Acid.
Modern Practice of Surgery.
Monro on Dropsy.
Morgagni, Cook's, 2 vols.
Meade's Pharmacy.
Murray's Materia Medica.
Miner and Tully on Fevers.
Mutter on Loxarthrus.
Moncrif on Waters.
Moss on Infants.
M'Murtrie's Vade Mecum.
Martinet's Therapeutics.
Milman on Scurvy.
Murray on the Arteries.
Maculloch on Remittents and Intermittents.
Maculloch on Malaria.
Maclean on Hydrothorax.
Mitchell's Chemistry.
Maygriere's Anatomy.
Morton on Consumption.
Maygriere's Midwifery.
Nuttall's Botany.
Orfila on Poisons
Oliver's Physiology.
Phrenology, Combe's
Phrenology, Spurzheim's
Phrenology, Calvert's
Pocket Anatomist.
Potts' Surgery, 2 vols.
Prout on the Urinary Organs, by Colhoun.
Phillips on the Laws of the Vital Functions.
Phillips on Indigestion.
Paris's Pharmacologia.
Parr's Medical Dictionary, 2 vols.
Paris's Medical Chemistry.
Paris on Diet.
Pemberton on the Viscera.
Pringle on Diseases of the Army.
Pott on Hydrocele.
Physician's Vade Mecum.
Phillips' Mineralogy.
Paxton's Anatomy, 2 vols.
Phillips on Diseases.

Parsons on Anatomical Preparations.
Parrish's Surgical Observations.
Parmly on the Teeth.
Pritchard on Insanity.
Plumbe on the Skin.
Ramsbotham's Midwifery.
Richerand's Physiology.
Rush on the Mind.
Rush's Hillary.
Rush's Cleghorn.
Rush's Sydenham.
Robertson's Conversations.
Robinson's Catalogue of Minerals.
Rush on the Voice.
Rush's Pringle.
Ryland on the Stethoscope.
Ricketson on Health.
Ratier's Formulary.
Read on Consumption.
Ryan's Medical Jurisprudence.
Ryan's Lectures on Marriage.
Swediaur on Syphilis.
Scudamore on Gout and Rheumatism.
Smith on Typhus Fever.
Shaw's Manual of Anatomy.
Stephenson on the Eye.
Struve on Suspended Animation.
Senac on Fevers.
Smith's Grammar of Botany.
Scofield on Cow Pock.
Saunders on the Liver.
Saissy on the Ear.
Surgeons' Vade Mecum.
Silliman's Chemistry, 2 vols.
Smith on Fevers.
Surgeon Dentist's Manual.
Sylva Americana.
Syme's Surgery.
Snell on the Teeth.
Smith on the Arteries.
Thatcher's Practice.
Teale on Neuralgia.
Thatcher's Dispensatory.
Thatcher on Hydrophobia.
Trotter on Drunkenness.
Timbrel on Ruptures.
Travers on the Eye.
Thompson on Varioloid.
Turner's Chemistry.
Thomas' Domestic Medicine.
Thornton's Botany.
Trotter on Nervous Temperament.
Thomson on Inflammation.
Tavernier's Operative Surgery.
Torry's Botany.
Tweedie on Fever.
Tuson's Dissector's Guide.
Ure's Chemical Dictionary, 2 vols.
Underwood on Diseases of Children.
United States Pharmacopœia.
Vought on Bowel Complaints.
Velpeau's Midwifery.
Velpeau's Anatomy, 2 vols.
Wistar's Anatomy, 2 vols.
Warner's Surgery.
Webster's Brande's Chemistry.
Willan on the Skin.
Williams' Jurisprudence.
Winslow's Anatomy.
Wilson on Febrile Diseases.
Wilson on Spotted Fever.
Webster's Chemistry.
Wilson, Philip, on Diseases.
Williams on the Lungs.
Wood and Bache's Dispensatory.
Williams' Chatechism of Medical Jurisprudence.

NEW BOOKS

RECENTLY PUBLISHED

BY

JOSEPH G. AUNER,

NO. 343 MARKET STREET,

PHILADELPHIA.

HORNER'S PRACTICAL ANATOMY.

Lessons in Practical Anatomy, for the Use of Dissectors. By W. E. Horner, M. D., Professor of Anatomy in the University of Pennsylvania, Surgeon at the Philadelphia Hospital, *Blockley*, &c. 1 vol. 8vo. 3d edition, enlarged and improved.

HARE'S CHEMISTRY.

A Compendium of the Course of Chemical Instruction in the Medical Department of the University of Pennsylvania. By Robert Hare, M. D., Professor of Chemistry in the University of Pennsylvania. 1 vol. 8vo.

GODDARD ON THE NERVES.

Plates of the Cerebro-Spinal Nerves, with references, for the use of Medical Students. By Paul B. Goddard, M. D., Demonstrator of Anatomy in the University of Pennsylvania, Member of the Academy of Natural Sciences, of the Philadelphia Medical Society, &c., &c. 1 vol, quarto. Twelve plates.

"We recommend this volume to form a part of the library both of the student and practitioner."—*American Medical Library and Intelligencer.*

GODDARD ON THE ARTERIES.

Plates of the Arteries of the Human Body with copious references. By Paul B. Goddard, M. D., Demonstrator of Anatomy in the University of Pennsylvania, Member of the Academy of Natural Sciences, of the Philadelphia Medical Society, &c., &c. 1 vol. 4to. plates.

CHASE ON HERNIA.

A treatise on the *Retention and Radical Cure of Hernia*, with advice to patients on the precautionary measures required to insure their safety; and an analysis of the instruments employed in the treatment of this disease; with a detailed account of numerous improvements: addressed to the profession and the public; with plates. By Heber Chase, M. D., Honorary Member of the Philadelphia Medical Society, &c. 1 vol. 8vo.

HAINES' CATECHISM ON CHEMISTRY.

Catechism on Chemistry, adapted to the Course of Lectures delivered in the University of Pennsylvania. By Isaac S. Haines, M. D. 1 vol. 18mo.

LOBSTEIN ON THE SYMPATHETIC NERVE.

A Treatise on the Structure, Functions, and Diseases of the Human Sympathetic Nerve, illustrated with plates. By John Frederick Lobstein, Professor of Clinical Medicine and Pathological Anatomy in the Medical Faculty of Strasburg, First Obstetric Physician to the City Hospital, and Member of many Learned Societies.—Translated from the Latin, with notes, by Joseph Pancoast, M. D. 1 vol. 8vo.

BARTON'S MATERIA MEDICA AND BOTANY.

Outlines of Lectures on Materia Medica and Botany, delivered in Jefferson Medical College, Philadelphia. By William P. C. Barton, M. D. 2 vols. 12mo.

MASON ON SELF KNOWLEDGE.

A Treatise on Self Knowledge, showing the nature and benefit of that important science, and the way to attain it; intermixed with various reflections and observations of human nature. By John Mason, A. M. 1 vol. 18mo.

The proper study of mankind is man.—*Pope.*

SANDFORD AND MERTON.

The History of Sandford and Merton. By Thomas Day. 1 vol. 12mo.

DYER'S SACRED MUSIC.

Dyer's Selection of Sacred Music, consisting of about three hundred approved Psalm and Hymn Tunes; from the works of the most esteemed authors, ancient and modern arranged for four voices,and adapted to all the metres in general use amongst the various religious denominations; and a concise Introduction to the Art of Singing, with Lessons and Examples, according to the English and Italian methods. By Samuel Dyer. 1 vol. 8vo.

DYER'S ANTHEMS.

A selection of upwards of Eighty favourite and approved Anthems, Set Pieces, Odes, and Choruses, from the works of the most approved authors; many of which have never before been published in this country, and several of them are original, and composed expressly for this work; with Biographical Sketches of the Several Composers. By Samuel Dyer. 1 vol. super-royal 8vo.

DYER'S CHORUSES.

Choruses, Solos, Duetts, and Recitatives, from the works of Handel, Haydn, Mozart, Beethoven, and other composers of the first eminence, arranged in full vocal score, and interspersed with Notes and Explanatory Remarks. By Samuel Dyer. 1 vol. 4to.

O'CONNOR'S GRAMMAR.

A simplified and expeditious method of teaching English Grammar; chiefly intended as an Evening Exercise for Students. By J. O'Connor. 1 vol. 4to.

CARLL'S ARITHMETIC.

An Introduction to Arithmetic. By M. M. Carll. 1 vol. 18mo.

Porto. J. J. Clarke

J — Hampton

Poetry. 94 lines

How sad was the wind & chill the wave
that wandered on the deep